[redacted]

ECKENFELDER INC.

VOLUME I

IN SITU VAPOR STRIPPING PILOT-SCALE TREATABILITY STUDY LORD-SHOPE LANDFILL GIRARD TOWNSHIP, PENNSYLVANIA

Prepared for:

LORD CORPORATION
Erie, Pennsylvania

Prepared by:

ECKENFELDER INC.
227 French Landing Drive
Nashville, Tennessee 37228
(615) 255-2288

January 1993

6735

VOLUME I

TABLE OF CONTENTS

VOLUME I

TABLE OF CONTENTS (Continued)

VOLUME I

TABLE OF CONTENTS (Continued)

VOLUME I

TABLE OF CONTENTS (Continued)

VOLUME I

TABLE OF CONTENTS (Continued)

VOLUME II

APPENDICES

TABLE OF CONTENTS (Continued)

VOLUME I

LIST OF TABLES

VOLUME I

LIST OF TABLES (Continued)

VOLUME I

LIST OF TABLES (Continued)

VOLUME I

LIST OF TABLES (Continued)

VOLUME I

LIST OF FIGURES

VOLUME I

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

VOLUME I

LIST OF FIGURES (Continued)

[a]Photograph.

VOLUME I

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

EXECUTIVE SUMMARY

The Lord-Shope Landfill Superfund Site is located in Girard Township in northwestern Pennsylvania. After the Remedial Investigation and Feasibility Study (RI/FS) for the site were completed, USEPA issued their Record of Decision (ROD) which calls for certain remedial actions to be accomplished at the site. One of these actions is the employment of in situ vapor stripping (ISVS) to reduce the quantity of volatile organic compounds (VOCs) in the subsurface.

Lord Corporation is conducting the Remedial Design and Remedial Action (RD/RA) at the site under the terms of a Consent Decree. As part of the RD being prepared by ECKENFELDER INC. and Lord Corporation, treatability studies were conducted to help develop design criteria. These pilot-scale field studies further develop the treatment technologies which were assessed on a smaller scale during the RI/FS.

In November 1991, the ISVS treatability study was begun at the Lord-Shope Landfill. The work was to proceed according to a Work Plan developed by ECKENFELDER INC. in July 1991 and subsequently approved by USEPA. The treatability study addressed the vapor stripping of VOCs from beneath the cap of the landfill and from select areas of soil surrounding the landfill (known as the toe and crest areas). Unanticipated levels of methane present in the landfill precluded the execution of the treatability study as initially designed because the pilot-test system, per the designed safeguards, shut down when the levels of methane reached the mobile vapor stripping unit. Because the levels of methane prohibited safe operation, the mobile in situ vapor stripping unit and associated equipment were redesigned, as was the Work Plan, to address these contingencies and the ramifications of these contingencies. Sampling of the toe and crest areas proceeded as scheduled, and USEPA then approved the Work Plan modifications.

The redesigned treatability study began in late March 1992. Since the presence of methane precluded the determination in November 1991 of whether the landfill was air tight and needed passive vents to implement in situ vapor stripping, another course of action was taken. The configuration of the extraction well and monitoring probes installed at the cap and the subsequent design of the revised treatability study included testing of both scenarios, i.e., an air tight system which required

passive vents to provide adequate air for stripping and a pneumatically permeable system which would be operated in a traditional manner without passive vents. The test design minimized breaching of the cap. The testing included a 75 hour operation without passive vents. This was followed by an 8 hour test in which passive vents were operational. Another component of the treatability study was the "slug" test which was used to determine an approximate diffusion rate for the VOCs. This information is essential since the latter part of remediation by vapor stripping is controlled by non equilibrium kinetics and the ROD, given the unique circumstances of the capped landfill, established that the endpoint of ISVS during the RA is to be based upon the limits of technology performance.

Overall, the ISVS treatability study was successful and volatile organic compounds were easily removed from the landfill during the 75 hour testing. Large amounts of methane were removed. Vinyl chloride was also present in the extracted gas. The vinyl chloride is a product of the anaerobic degradation of chlorinated materials which were disposed of in the landfill. The presence of methane and vinyl chloride, which are both small, labile molecules, needs to be specifically addressed during the design of the off gas treatment system. The testing with the passive vent configuration indicated that as much as 97 percent isolation of the extraction well could be achieved with only three passive vents. Ninety-seven percent isolation means that only three percent of the air extracted enters from outside the volume defined by the three passive vents. The ability to minimize the number of extraction wells and/or passive vents during design of the full scale system is important since each installation involves breaching the impermeable cap.

The analysis of data generated during testing indicates that there is pneumatic permeability at the perimeter of the landfill that would permit, upon first assessment, a traditional vapor extraction operation at the landfill, and that passive vents are not required. The radius of influence of the extraction well observed during the test was in excess of 200 feet and may extend under the entire capped area. The results of the slug test indicated that the diffusion constant is on the order of a half to one-and-a-half hours. This information will be used in developing the monitoring protocol and cutoff parameters to determine cleanup completion.

The results of the toe and crest study indicated the presence of volatile organic materials in the soil, although at low vapor concentrations as compared to the landfill, the most prevalent being tetrachloroethene. Some vinyl chloride was also detected. No methane was detected. There seemed to be a relatively small zone of influence in the crest wells. The high water level at the toe wells tended to clog the well screens. These considerations will also have to be addressed during full scale design.

SECTION 1

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

The Record of Decision (ROD) for the Lord-Shope Landfill Site was signed by the Regional Administrator for the United States Environmental Protection Agency (USEPA) Region III on June 29, 1990. The selected remedy for the Site calls for the use of in situ vapor stripping (ISVS) to remove volatile organic compounds (VOCs) from the landfill itself and surrounding soils, a source control treatment measure. The surrounding soils to be remediated are known as the "landfill toe area" located to the east and northeast of the landfill and the "crested soil area" located to the southeast of the landfill.

Lord Corporation has entered into a Consent Decree with the United States to implement the Remedial Design/Remedial Action (RD/RA) at the Site.

During the Feasibility Study (FS) for the Site, results from preliminary field studies, laboratory simulations, and mathematical modeling established that ISVS was a compatible and feasible source control measure (ECKENFELDER INC., January 1990). Although a conceptual design was prepared for the application of ISVS to the site, a larger scale (pilot) field study was required to generate final design criteria and cleanup criteria/performance information. The Work Plan (ECKENFELDER INC., July 1991) set forth the protocols for conduct of the ISVS pilot-scale treatability study for the site and also included, as necessary and sufficient, construction quality assurance provisions for installation and operation of the pilot test systems. USEPA approved the Work Plan October 25, 1991.

This report describes the conduct of the ISVS pilot-scale treatability study as described in the Work Plan as well as the minor changes made to the Work Plan during the course of the study. The results from the study are presented with discussion and evaluation.

1.2 SITE BACKGROUND

In this section, the location, physical features, and a brief history of the landfill are presented.

1.2.1 Site Location

The Lord-Shope Landfill Site is located in Girard Township, Erie County, Pennsylvania (Figure 1-1). The property encompasses approximately 25 acres and is situated between US Route 20 to the north and Interstate Route 90 to the south. The property is bounded on the east by Pieper Road, an apple orchard and vineyard to the south, an evergreen nursery to the west, and overgrown cropland to the north. The nearest population center, Girard Borough, is located two miles to the northeast. The only nearby residences are located along Pieper Road, to the east and northeast and along Route 20 to the north. The Overlake Golf Course is located close to the site to the north.

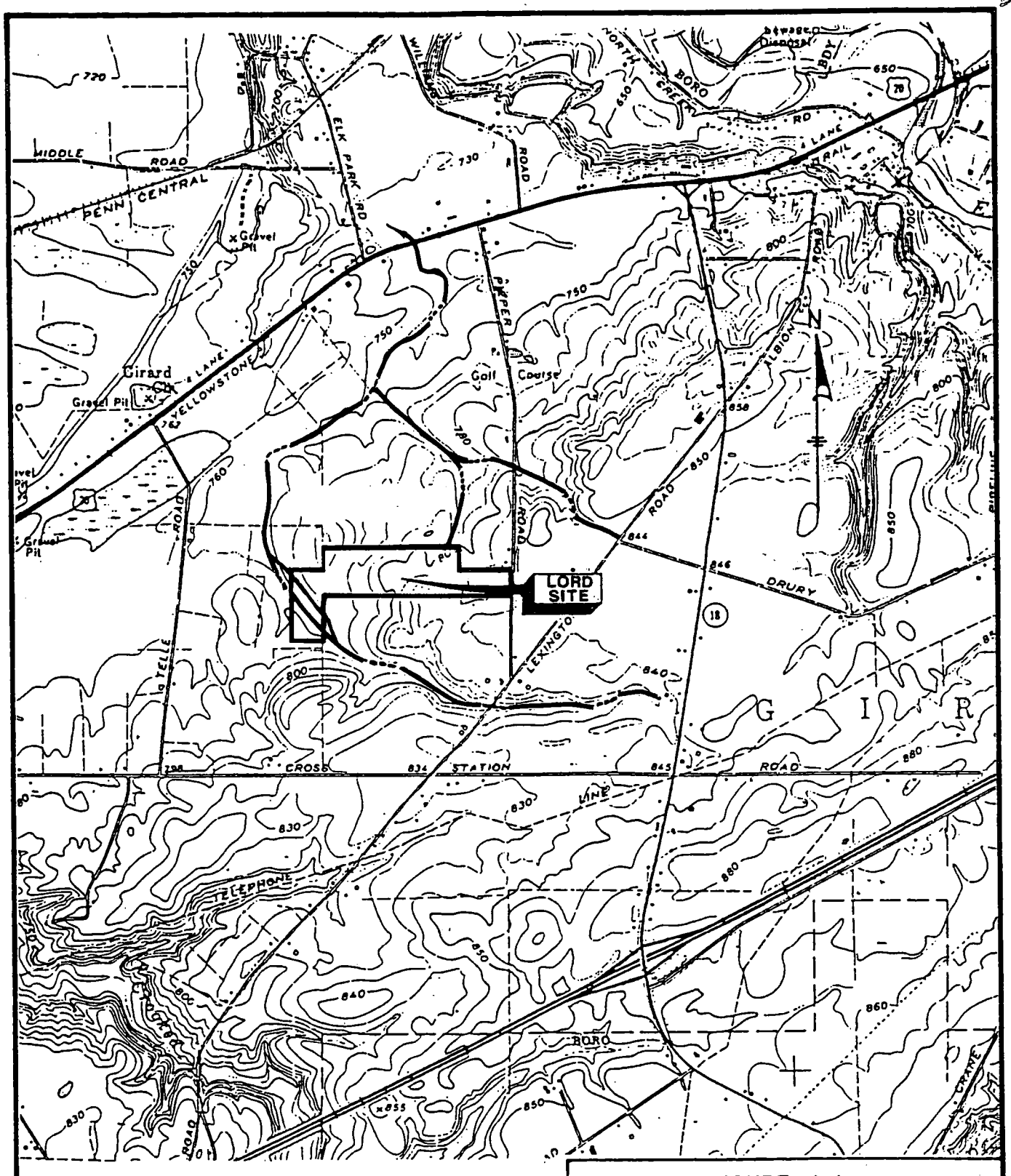
The landfill occupies approximately four (4) acres of the central portion of the property (Figure 1-2). The landfill area is fenced with four access gates; the main gate is in the southeast corner with a road leading in from Pieper Road. The specific areas targeted for remediation by ISVS are the capped landfill, the toe of the landfill, and the crested soil southeast of the landfill. A site work/storage building is located east of the landfill within the fenced area.

1.2.2 Site History and Waste Components

The Lord-Shope Site was formerly used as an industrial waste landfill from the late 1950s until 1979. The site was owned and operated by Melvin Shope. Mr. Shope, an employee of Lord Corporation in the Maintenance Department, hauled and disposed of wastes generated from Lord's 12th Street, Erie, Pennsylvania and Saegertown, Pennsylvania plants. No wastes other than those generated by these Lord Corporation facilities are reported to have been disposed at the Lord-Shope site.

The waste contained in the landfill was disposed of directly upon the original ground surface. On this basis, the thickness of the waste does not exceed a maximum of 20 feet. The waste reportedly consists primarily of waste rubber scrap, demolition debris, pallets, and paper. However, drummed chemical wastes consisting primarily of spent adhesives, waste paint, and paint sludges were also disposed in the landfill. These contained non-halogenated compounds including ketones, toluene, xylene, and

ORIGINAL (Red)



SOURCE: ALBION, (1959, REV. 1969)
PA. 7.5' QUADRANGLE

2000 0 2000
scale feet

MAP LOCATION

FIGURE 1-1
LORD - SHOPE LANDFILL SITE
LORD CORP.
GIRARD TWP., ERIE COUNTY, PA

6114 10/91

ECKENFELDER INC.
Nashville, Tennessee
Mahwah, New Jersey
Rochester, New York

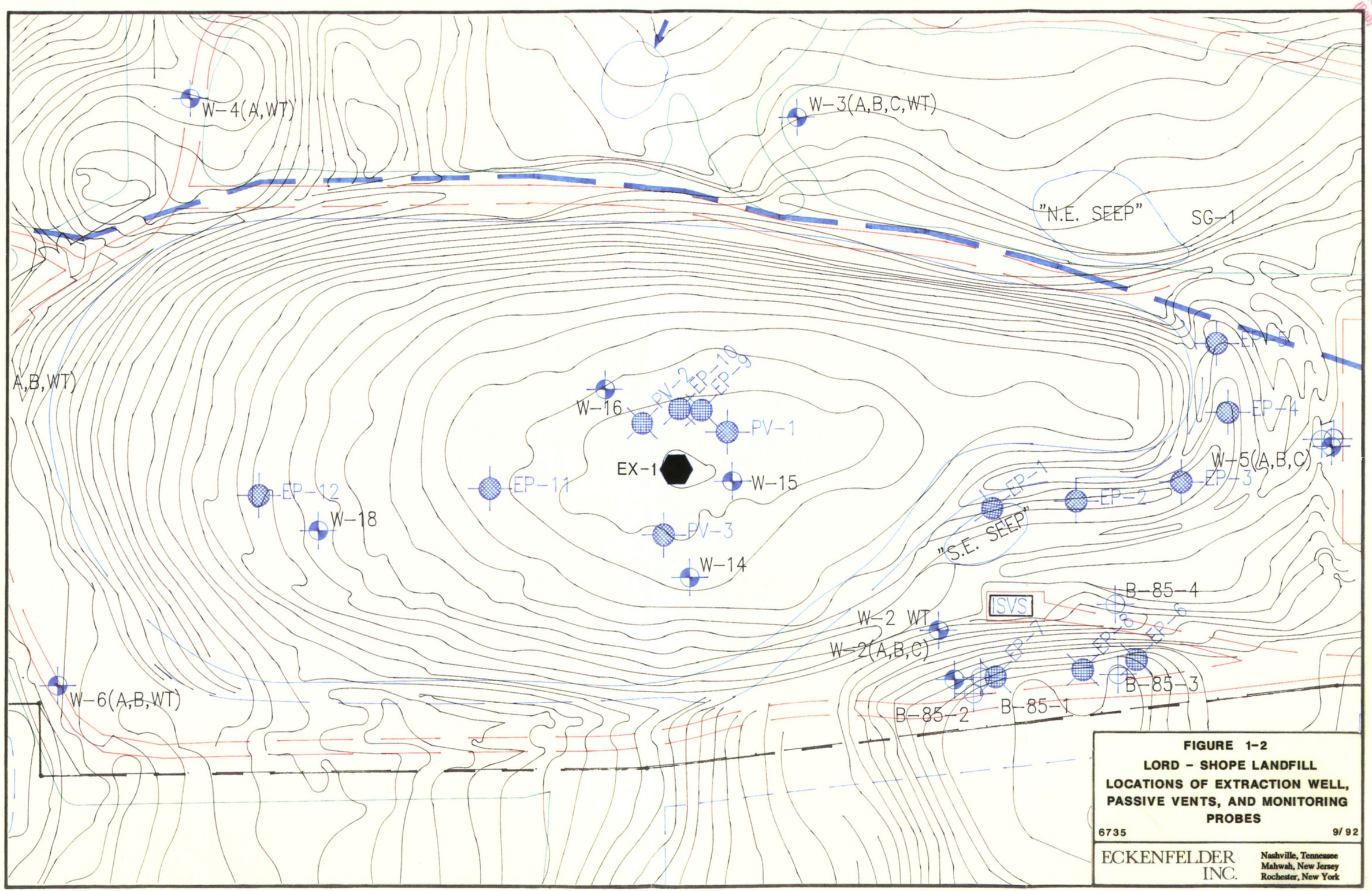


FIGURE 1-2
LORD - SHOPE LANDFILL
LOCATIONS OF EXTRACTION WELL, PASSIVE VENTS, AND MONITORING PROBES

6735 9/92

ECKENFELDER INC.
Nashville, Tennessee
Mahwah, New Jersey
Rochester, New York

naphtha, with only small proportions of chlorinated compounds. Minor quantities of drummed wastes including chlorinated paint and degreasing solvents, non-polychlorinated biphenyl (non-PCB) cutting oils, and miscellaneous acids and caustics were also deposited in the landfill. Disposal of drummed waste was discontinued following a fire that occurred at the landfill in June 1971. Table 1-1 identifies the chemicals received at the Lord-Shope landfill during its operation or detected in samples at the Site.

A remedial action in accordance with the Consent Order & Agreement was undertaken in the Fall of 1982 and Spring of 1983. The purpose of this work was to reduce the volume of leachate generated and released from the landfill and to provide for post-construction monitoring. The remediation included removal of exposed drums and construction of a composite cap, an upgradient cut-off wall, and a storm water drainage system. The combined effect of the composite cap and upgradient cut-off wall has been to reduce the amount of leachate generated by more than 99 percent. The storm water drainage system has served to mitigate soil erosion and reduce the possibility of overland flow contamination.

1.3 REMEDIAL TECHNOLOGY DESCRIPTION

In response to the requirements of the Superfund Amendments and Reauthorization Act of 1986 (SARA) to reduce the volume, mobility, or toxicity of contaminants, and based upon preliminary site testing, it is considered feasible to reduce the presence of volatile and some semivolatile constituents in and around the landfill using an ISVS technique. The technique is also sometimes called soil vapor extraction (SVE), soil vacuuming, soil venting, and soil gas extraction.

The selected remedial option is also consistent with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and SARA requirements for:

- cost effectiveness
- consistency with (waived) Applicable or Relevant and Appropriate Requirements (ARARs)
- protection of human health and the environment
- permanency

TABLE 1-1

LIST OF VOCs RECEIVED AT OR DETECTED IN ENVIRONMENTAL MEDIA AT LORD-SHOPE LANDFILL

Acetone
Benzene
2-Butanol
2-Butanone (Methyl Ethyl Ketone)
Chlorobenzene
Chloroform
Chloromethane (Methyl chloride)
Chloroethylene (Vinyl chloride)
Cyclohexanone
1,1-Dichloroethane
Dichloromethane (Methylene chloride)
4-Methyl-2-pentanol
4-Methyl-2-pentanone (Methyl Isobutyl Ketone)
2-Propanol (Isopropyl alcohol)
trans-1,2-Dichloroethylene
Tetrachloroethene (Tetrachloroethylene)
1,1,2,2-Tetrachloroethane
Tetrahydrofuran
Toluene
Trichloroethene (Trichloroethylene)
Xylene

These conclusions are based upon the ROD and the FS. This study included the results of various laboratory simulations, mathematical modeling, and small scale field testing at the capped landfill, the toe of the landfill, and the crested soil southeast of the landfill.

The ISVS process can be used to remove VOCs and some semivolatile organic compounds (SVOCs) from landfills, fill areas, and vadose zone soil. During ISVS, ambient air is introduced into the soil/waste through the soil or a passive vent pipe system and is withdrawn through a vapor extraction well. As the air passes through the contaminated subsurface environment, the VOCs sorbed onto the soil or other buried debris are partitioned into the air and are removed as the air is extracted. Figure 1-3 is a generalized diagram of an ISVS system.

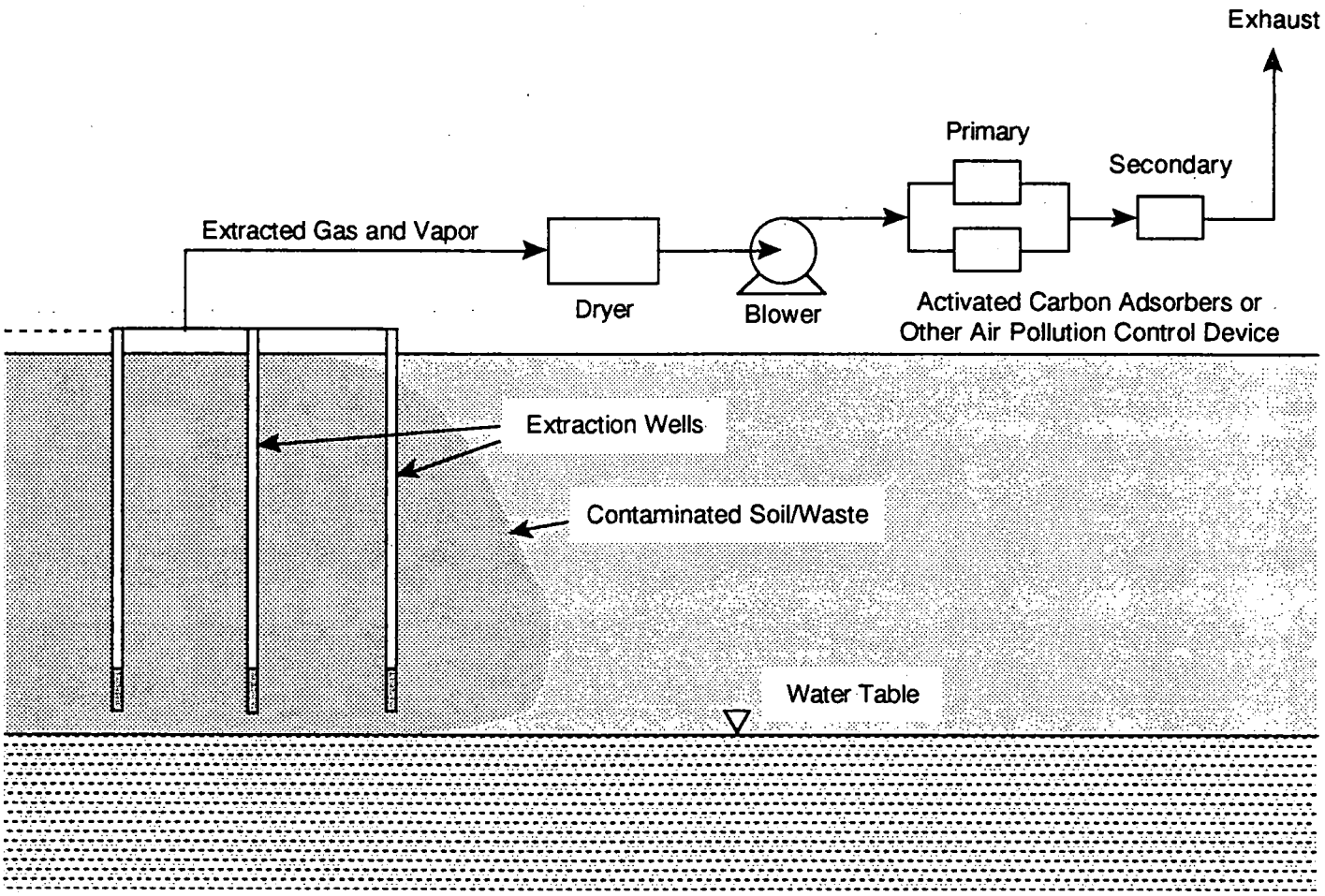


Figure 1-3. Generalized Diagram of ISVS System

SECTION 2

2.0 WORK PLAN SUMMARY

In this section, the Work Plan for the ISVS treatability study is summarized. Emphasis is placed on the actual work done, and modifications made to the original Work Plan (ECKENFELDER INC., July 1991) are noted. Hereafter the original Work Plan will be referred as "the Work Plan" without further reference.

2.1 TEST OBJECTIVES

The overall objectives of this pilot-scale treatability study were: 1) evaluation of performance of ISVS at the Lord-Shope Landfill under conditions analogous to full-scale operation; and 2) development of a data base for full-scale design and cost estimating. Included in these broad objectives were the more specific goals of: better qualitation/quantitation of the stripped soil gas (from the landfill, toe, and crest areas); assessment of the quantity of ambient air available for stripping within the landfill; assessment of the potential for fire within the landfill; and evaluation of the capacity of activated carbon for extracted soil gas treatment under site-specific conditions. These objectives were met through a series of specially designed tests described in Sections 2.0 and 3.0 of this report.

The Work Plan stated that data generated during the treatability testing would be used in a series of mathematical models for ISVS developed by ECKENFELDER INC. to further meet these goals and overall objectives. However, use of mathematical models for ISVS requires knowledge about the initial concentration of the contaminants in the site. The heterogeneity of the fill precludes obtaining meaningful soil concentration data as could be developed for more traditional sites contaminated soil. Therefore, the traditional mathematical models for ISVS could not be applied in this treatability study to estimate clean time. Other approaches will be employed to compensate.

2.2 TEST DESIGN

The test design for this treatability study, as described in the Work Plan, was followed as closely as the site conditions permitted. The mobile pilot-scale ISVS unit designed by ECKENFELDER INC. and the proprietary portable ISVS unit were

used at the landfill to perform the tests (see Section 2.3 for a description of these units). All effort was made in the implementation of the test design of the treatability study to minimize breaching the landfill cap without jeopardizing the value of the data. Similarly, planning effort was expended to minimize waste generated during the testing program.

2.2.1 Changes to the Test Design

Table 2-1 is a summary of the major components of the treatability study as proposed in the Work Plan. Copies of the Standard Operating Procedures (SOPs) and other pertinent information for the completion of these activities were included in the appendices of the Work Plan. Figure 2-1 is a task diagram of the testing sequence proposed in the Work Plan for the capped landfill. The tasks listed in Figure 2-1 and the components in Table 2-1 were followed except where site conditions required an alteration.

Table 2-2 provides an overview of the actual sequence of operations for the Treatability Study. The components' designation letters from Table 2-1 are listed beside their corresponding task in Table 2-2. Two testing periods were used to complete this Treatability Study. The first period will be called the "Part 1 Testing" and the second, the "Part 2 Testing." Tasks 1 through 9 in Table 2-2 were performed as the Part 1 Testing from October 30, 1991 through November 15, 1991; Tasks 11 through 16 were performed as the Part 2 Testing from March 22, 1992 through April 2, 1992. Task 10 was an evaluation of the data and information generated by Part 1 Testing that led to the implementation of Part 2 Testing. The primary changes made to the Work Plan correspond to components C, D, and E in Table 2-1; Steps 2 through 7 in Figure 2-1 were eliminated.

Part 1 Testing began by transferring the mobile pilot-scale ISVS unit to the site and preparing it for operation. Rather than the indirect method proposed in the Work Plan (Component C, Table 2-1), a new extraction well was installed and used for flow testing (Tasks 3-4, Table 2-2). Because the new extraction well was to be used for the ISVS tests, it was decided that flow testing should be done with this well as outlined in Component D; this change was also more cost-effective because of the time saved by omitting unnecessary tests. When the flow test was attempted, the presence of methane in the extracted soil gas caused the mobile pilot-scale ISVS unit

TABLE 2-1

MAJOR COMPONENTS OF THE TREATABILITY STUDY PROPOSED IN THE WORK PLAN

Location On Site	Component	SOP Status
Landfill	A: Transfer mobile pilot-scale ISVS unit to site Set up ISVS unit Connect power	
	B: Check out operational status of ISVS unit	Y[a]
	C: Check integrity of existing extraction wells Check if existing extraction wells are adequate to use in "D"	Y Y
	D: Install new extraction well Test need for installation of passive vents Install passive vents (optional)[c]	Y X[b] X
	E: Install monitoring probes (optional)[c]	Y
	F: Operate mobile unit for 4 days while monitoring: Vacuum — CH_4 Content Flow rates — CO_2 Content Temperature — VOC Concentration Opacity Trailer Ports (and field probes, if present)	X, Y
	G: Take soil gas samples for analysis during above 4-day operation of mobile unit per schedule	Y
	H: Cease operations/perform maintenance	Y
	I: Begin pulse/slug test (to evaluate non-equilibrium effects)	X
	J: Sample per schedule	X
	K: Cease operations/perform maintenance/make travel ready	Y
Toe and Crested Soil Areas	L: Open existing wells and check status Develop well/monitor flow vacuum Sample per schedule Cease operations/perform maintenance/prepare unit for shipment	X, Y Y
	M: Close-off wells	Y

[a]SOP status Y indicates existing protocols, developed by ECKENFELDER INC. and previously employed.

[b]SOP status X indicates detailed protocols developed specifically for this study.

[c]Listed as "optional" in the Work Plan, but due to site conditions, both passive vents and monitoring probes were actually installed.

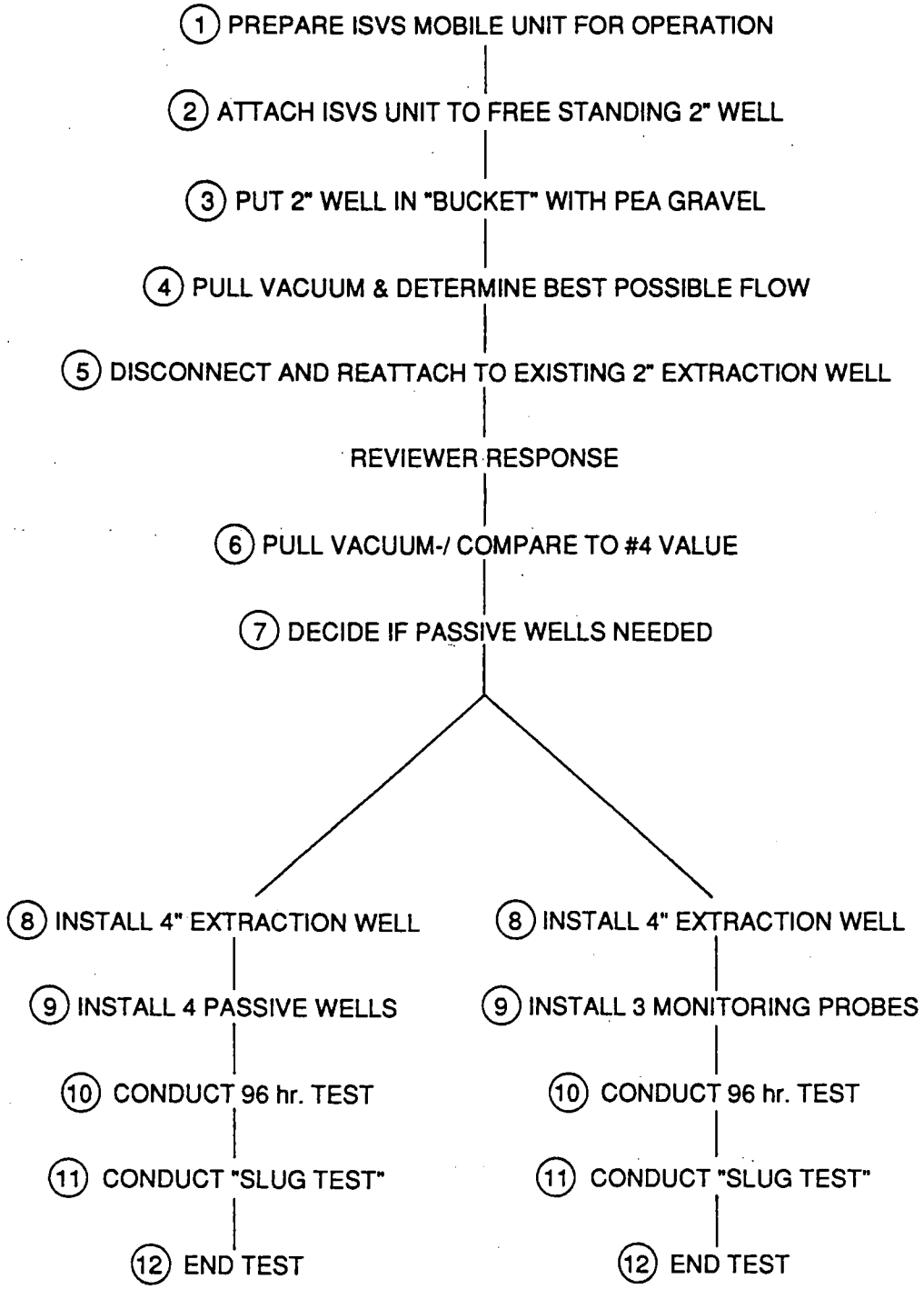


FIGURE 2-1 TASK DIAGRAM OF TREATABILITY STUDY AT LANDFILL AS PROPOSED IN THE WORK PLAN

TABLE 2-2

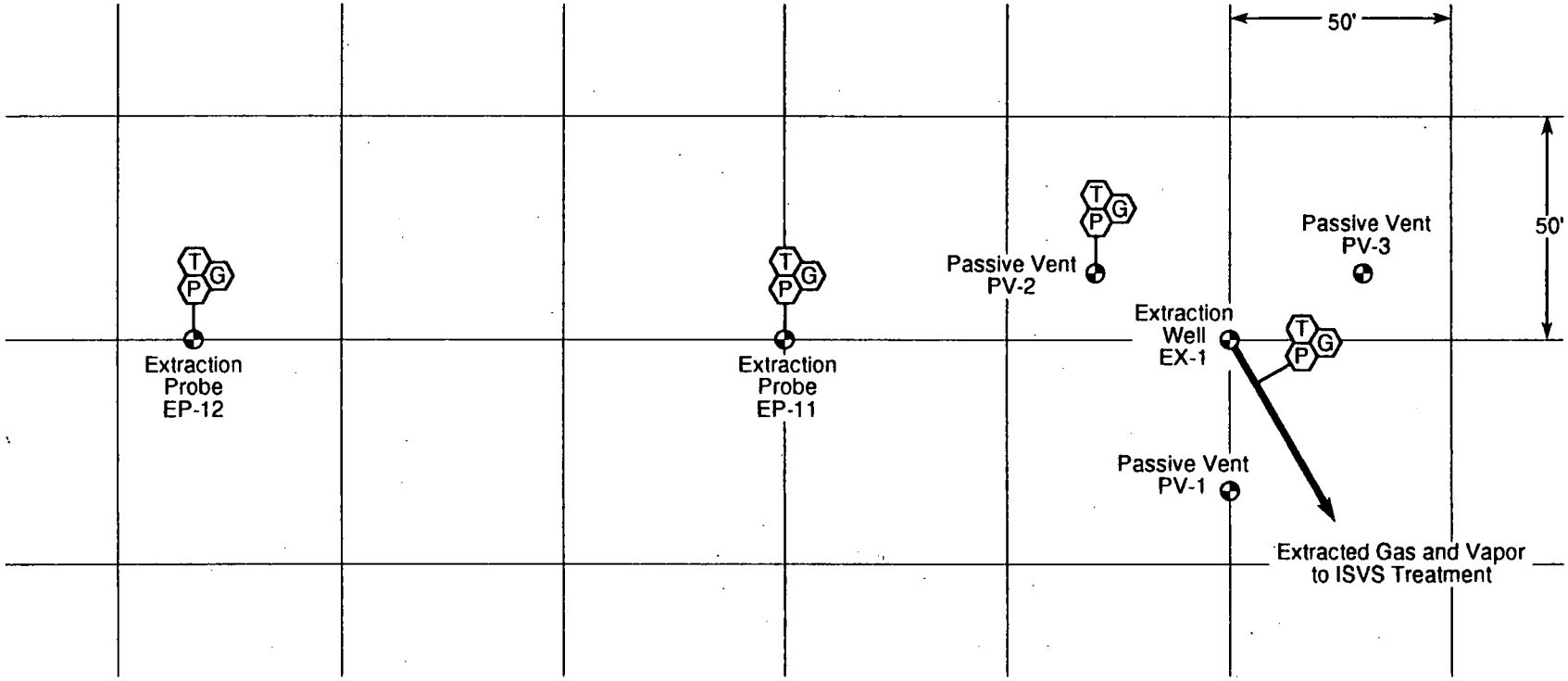
ACTUAL SEQUENCE OF OPERATIONS FOR ISVS TREATABILITY STUDY

	Description of Operation	Component of Work Plan (Table 2-1)
1.	Mobile pilot-scale ISVS Unit transferred to site and prepared for operation	A, B
2.	Extraction well installed	D
3.	Extraction well connected to mobile pilot-scale ISVS unit	D
4.	Flow test attempted; blowers shut off by in-line explosimeter	D
5.	Valve installed to dilute extracted gas with ambient air	New[a]
6.	Three passive vents and two monitoring probes installed	D, E
7.	Toe and crest testing performed using portable ISVS unit	L, M
8.	Soil gas samples taken at newly-installed extraction well, passive vents, and monitoring probes	New
9.	Mobile pilot-scale ISVS unit prepared for temporary on-site storage (following travel-ready guidelines) until modifications could be made and weather permitted testing to continue	K
10.	Data generated by above activities evaluated and necessary changes made to Work Plan	New
11.	Mobile pilot-scale ISVS unit prepared for operation with new explosion-proof blower and associated equipment as dictated by changes made to Work Plan	New
12.	75-hour ISVS test conducted with passive vents closed	F, G
13.	8-hour ISVS test conducted with passive vents open	F, G
14.	Pulse/Slug tests conducted with passive vents closed	I, J
15.	Toe and crest testing completed using portable ISVS unit	L, New
16.	Mobile pilot-scale ISVS unit prepared for travel	K

[a]"New" indicates this was designed as testing was being performed to accomplish the test objectives given the site conditions.

to shut down (as designed) as a precaution against fire or explosion. This activated emergency alarm and automatic shut off system performance was consistent with the safeguards installed on the unit against such contingencies. Dilution of the extracted soil gas with ambient air was attempted but did not prevent the system shutdown. The system was designed to shut off at 20 percent of the Lower Explosive Limit (LEL) of methane (the LEL for methane is equivalent to 5 percent by volume methane in air). Dilution of the approximate 70 percent methane in the air flow did not reach this safety factor. Because it was not possible to operate the mobile pilot-scale ISVS unit safely and to complete the flow testing, a predetermination of the need for passive vents was not possible. Therefore, a compromise plan was agreed upon; three passive vents and two monitoring probes were installed instead of either four passive vents or three monitoring probes. These changes were communicated to and agreed upon by USEPA. The memos which document the changes and the reasons for them are included as Appendix A. The final design as shown in Figure 2-2 provided versatility for testing and evaluating the various options later in the program. The installation of these vents and probes are listed as part of components D and E in Table 2-1. The protocols outlined in the Work Plan were followed for installation with slight modification. Section 3.1.1 gives a detailed description of the installation of the extraction well, monitoring probes, and passive vents. Figure 2-2 shows the relative positions of the extraction well (EX-1), monitoring probes (EP-11 and EP-12), and passive vents (PV-1, PV-2, and PV-3); Table 2-3 gives the approximate distances from the extraction well to these probes, vents, and the mobile pilot-scale ISVS unit.

After the passive vents and monitoring probes were installed, the portable ISVS unit was used to take soil gas samples from the extraction well, the passive vents, the monitoring probes, and a previously installed monitoring probe, EP-9, (Task 8 in Table 2-2). The soil gas samples were taken in Tedlar® bags according to the procedures stated in Section 2.4 of this report. One set of samples was analyzed for VOCs, and another set was analyzed for methane content. These samples provided a representative survey of the contaminant concentrations in the landfill at the sampling locations. Appendix A contains the laboratory report on the methane concentrations from samples taken from the various well/probe locations at the cap. Methane concentrations ranged from 43 to 75 percent by volume. See Table 2-4. Concentrations of methane at these levels are consistent with the behavior of the



Legend:

→ Extracted gas flow

⬡ Gas sample, Pressure, and Temperature elements

⊕ Well and probe installations

ECKENFELDER INC.

Figure 2-2. Pilot-Scale ISVS System Cap Sampling and Instrumentation Diagram

TABLE 2-3

APPROXIMATE DISTANCES FROM EXTRACTION WELL TO PROBES, VENTS, AND MOBILE PILOT-SCALE ISVS UNIT

Reference Point	Approximate Distance from Extraction Well (EX-1) (feet)
Mobile Pilot-Scale ISVS Unit	250
PV-1	33
PV-2	33
PV-3	33
EP-11	100
EP-12	233

TABLE 2-4

RESULTS OF METHANE ANALYSIS FROM SAMPLES TAKEN AT THE CAP WITH THE SMALL EXPLOSION PROOF PUMP

Sampling Location	Distance to Extraction Well, ft	Concentration Methane, % Volume	Date; Time
Extraction well (EX)	--	53	11/6/92; 17:00
		66[a]	11/15/91; 11:09
		68[a]	11/15/91; 11:11
		70	11/15/91; 13:03
Passive Vent 1 (PV1)	30	67	11/15/91; 9:34
Passive Vent 2 (PV2)	30	65	11/15/91; 8:49
Passive Vent 3 (PV3)	30	70	11/15/91; 10:13
Extraction Probe 9 (EP9)	40	43	11/14/91; 17:38
Extraction Probe 11 (EP11)	100	75	11/14/91; 16:50
Extraction Probe 12 (EP12)	233	58	11/14/91; 16:01

[a]Blind duplicate analyses.

fail safe system on the mobile unit. The VOC data from the samples taken from the landfill using the small explosion proof pump are discussed briefly in Section 4.1.

The data generated by these samples, as well as the experiences with the equipment during the Part 1 Testing, were evaluated and necessary changes were made to the Work Plan so that the Part 2 Testing (Tasks 11 through 16, Table 2-2) could be completed. The changes made to the equipment and materials are described in Section 2.3. Because the actual ISVS tests were conducted during Part 2 Testing, we will consider each of these tests separately in the following section. A summary of activities during the Part 1 Testing and the data generated during that period were given in the interim report (ECKENFELDER INC., January 22, 1992). A copy of this interim report is attached as Appendix B.

2.2.2 ISVS Tests

Once the appropriate changes to the equipment were made to allow the operation of the mobile pilot-scale ISVS unit with extracted soil gas with high methane content, a continuous ISVS test (with passive vents closed) was carried out over a 75-hour period as outlined in Components F and G of the Work Plan (see Table 2-1). The testing period was shortened from the scheduled four day or 96-hour test period to allow for the addition of a second, shorter 8-hour ISVS test with the passive vents opened. During the 75-hour ISVS test, pressure/vacuum, flow rate, temperature, and opacity were monitored at the mobile pilot-scale ISVS unit. In addition, periodic gas monitoring was performed at the carbon exhaust. Temperature and vacuum were monitored on the landfill at each monitoring probe (EP-11 and EP-12), at one passive vent (PV-2), and at the extraction well (EX-1). Figure 2-2 shows the monitoring points used on the cap. A description of the equipment and materials is given in Section 2.3. Soil gas samples were collected at each of those points on the cap and at the carbon exhaust at scheduled sampling intervals. All samples were collected in one-liter Tedlar®[1] bags with stainless steel and Teflon®[2] fittings using a diaphragm gas sampling pump. (See Section 2.4 for the sampling plan.)

---

[1]Tedlar® is a registered trademark of E.I. duPont deNemours & Co., Inc.
[2]Teflon® is a registered trademark of E.I. duPont deNemours & Co., Inc.

The second, 8-hour ISVS test with passive vents opened was conducted after the 75-hour ISVS test. The same parameters were monitored at the mobile pilot-scale ISVS unit for this test as for the 75-hour test. Temperature and vacuum were monitored at the extraction well. Soil gas samples were collected in one-liter Tedlar® bags using the diaphragm gas sampling pump at the extraction well at scheduled sampling intervals. No soil gas samples were taken at the probes on the cap because the open passive vents isolated the extraction well from the rest of the landfill and no significant soil gas flow was anticipated from outside the triangle created by the three passive vents. Soil gas sampling and analysis were conducted according to the protocols outlined in Section 2.4 of this report.

2.2.3 Pulse/Slug Tests

The Pulse/Slug Tests were designed to evaluate the non-equilibrium effects at the Site which could be the controlling factor for the residual VOC concentration levels achievable within a given amount of time or, conversely, the time required to treat the site to specified target levels. Non-equilibrium conditions include desorption of the constituents of interest from the soil/waste particles and diffusion from the soil/waste particles into the interstitial air. The buried debris in the landfill may complicate the evaluation of non-equilibrium effects. These tests were carried out as outlined in Component I, Section 4.1.9.1 of the Work Plan, for a system without passive vents. The passive vents installed at the site were closed during this part of the testing. The pulse/slug tests were accomplished by injecting a large volume or slug of ambient air, approximately 2,500 cubic feet, into the landfill through the extraction well; allowing the air to reside in the landfill for a set period of time; then withdrawing a portion of the injected air from the extraction well and collecting soil gas samples. In the Work Plan, the same pipe was to be used for injecting the slug of ambient air and for extracting the soil gas. Due to the changes that were made to the equipment for the Part 2 Testing, it was determined that it would be better to use a separate pipe to introduce the ambient air to the landfill at the extraction well. The use of a separate air-injection pipe also assured the introduction of only clean, ambient air by eliminating any cross-contamination from the pipe used for extraction.

Five pulse/slug tests were carried out. The injected air had one-hour residence times for the first three tests; this repetition was used to assess the reproducibility of the

test. The next test had a 5-hour residence time for the injected air; the last test employed a 15-hour residence time. With each successive test, the soil gas should have been moved farther from the extraction well since each extraction withdrew less than half of the volume of ambient air that had been injected. The tests using the 5-hour and 15-hour residence times were designed to discover the maximum amount of materials that were transferring into the air (or soil gas) through non-equilibrium effects.

After the prescribed residence time, a portion of the slug of injected ambient air was extracted and sampled using the same procedure that had been used for 75-hour ISVS test and the 8-hour passive vent test. For each test, soil gas samples were collected when approximately 10 percent and 25 percent of the injected slug volume had been withdrawn. All soil gas samples were collected at the extraction well in one-liter Tedlar® bags using the diaphragm gas sampling pump. Sampling and analysis were according to the procedure in Section 2.4 of this report. Temperature and vacuum were also monitored at the monitoring probes (EP-11 and EP-12) and one passive vent (PV-2) during the conduct of these tests. This monitoring was not called for in the Work Plan; however, it was determined that the data might provide further information about the soil gas flow and temperature in the landfill.

2.2.4 Toe and Crested Soils Testing

The conduct of the landfill toe and crested soils testing was according to the description in Section 4.1.2 of the Work Plan. A group of eight wells had been installed during the April 1989 field work. The first task in Part 1 of the Treatability Study was to determine the status of the existing wells. Each well had been closed by polyvinyl chloride (PVC) screw caps. (The soil borings for each of these wells are provided in Appendix E of the Work Plan). No additional wells were placed in these areas; this approach was part of the effort to minimize the generation of hazardous materials/wastes during this Treatability Study and thereby to decrease the potential exposure of workers and the environment.

The portable ISVS unit was used to develop the eight wells during the Part 1 Test period. The soil gas flow rate and vacuum achieved by the portable ISVS unit at each well were monitored. Once a constant vacuum was reached, Tedlar® bag samples were collected for chemical-specific analysis. The soil gas samples were

analyzed for the same compounds that the soil gas extracted from the landfill was analyzed for. See Section 2.4 for the sampling and analysis plan for these tests. Soil gas samples were collected from each well on two consecutive days. After evaluation of the flow and vacuum data collected during the two days of testing, it was determined that another day of testing was required to obtain a more complete set of data so that the pneumatic permeability of the soil on the toe and crest could be calculated. This was accomplished with the portable ISVS unit during the Part 2 test period.

2.3 EQUIPMENT AND MATERIALS

The major components used in the treatability testing included a mobile pilot-scale ISVS unit, a portable ISVS unit, and associated monitoring probes, passive vents, and an extraction well. Gas monitoring and sampling equipment, a portable generator, temporary lighting, and other miscellaneous items were used in conjunction with the major components.

The mobile pilot-scale ISVS unit, designed by ECKENFELDER INC., was originally set up in the configuration shown in Figure 2-3 for initial Part 1 Testing in November 1991. During the Part 1 Testing, the discovery of high concentrations of methane in the landfill soil gas made it necessary to modify the pilot-scale system configuration (Figure 2-4) prior to continuing with the Part 2 Testing in March 1992. Both of the pilot-scale unit configurations consist of the following subsystems:

- Mobile Trailer
- Vapor Ducting
- Activated Carbon Adsorber
- Induced Draft Blower(s)
- Instrumentation and Controls

Each of the original pilot-scale ISVS subsystems is described in detail in Appendix A of the Work Plan. This section provides a brief overview of the mobile pilot-scale ISVS unit with emphasis on modifications made specific to the Lord-Shope testing.

As originally configured for the Part 1 Testing, the pilot-scale ISVS extracted gas treatment included a demister for entrained water removal, a heater to lower the

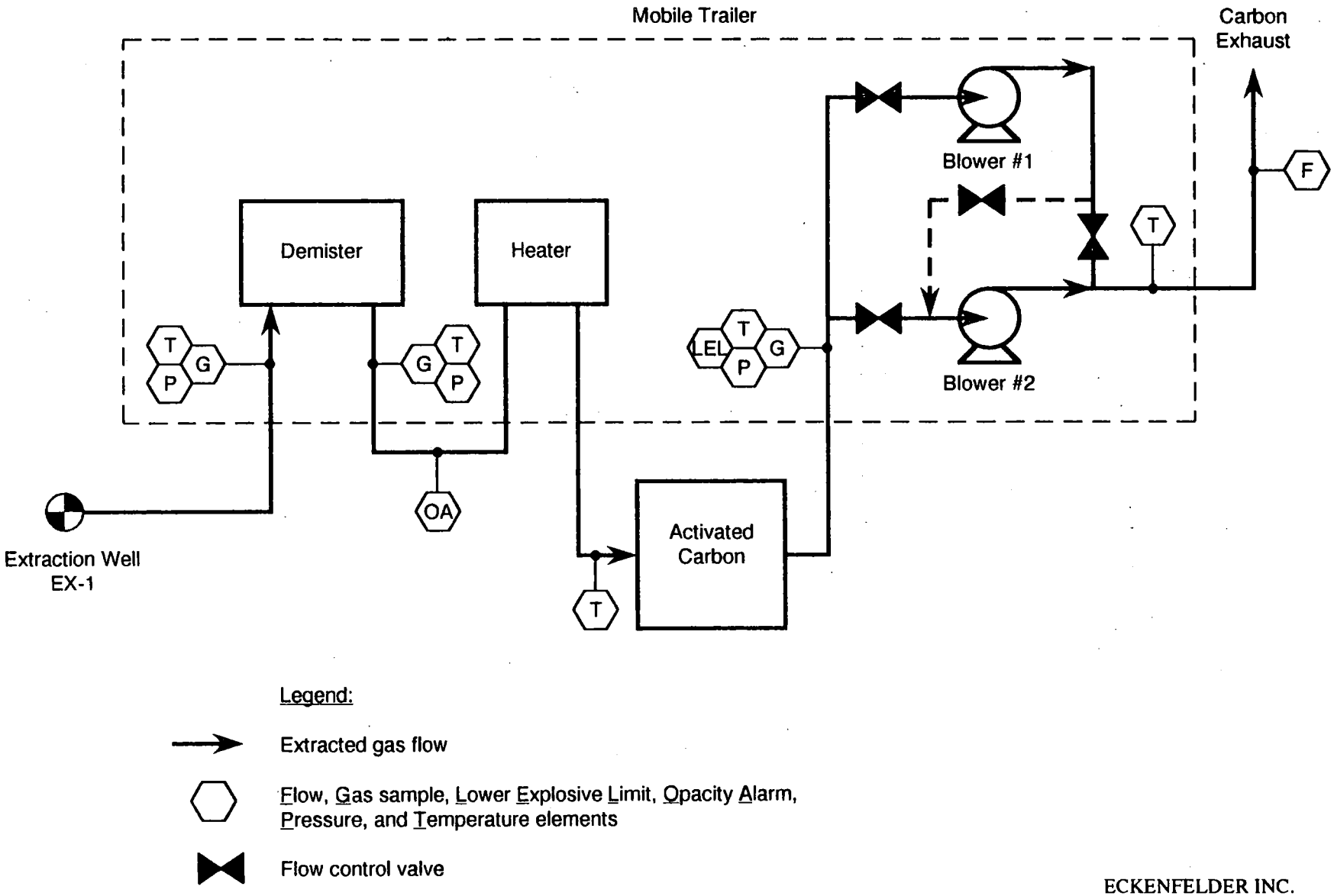


Figure 2-3. Pilot-Scale ISVS System Flow Diagram (Part 1 Testing)

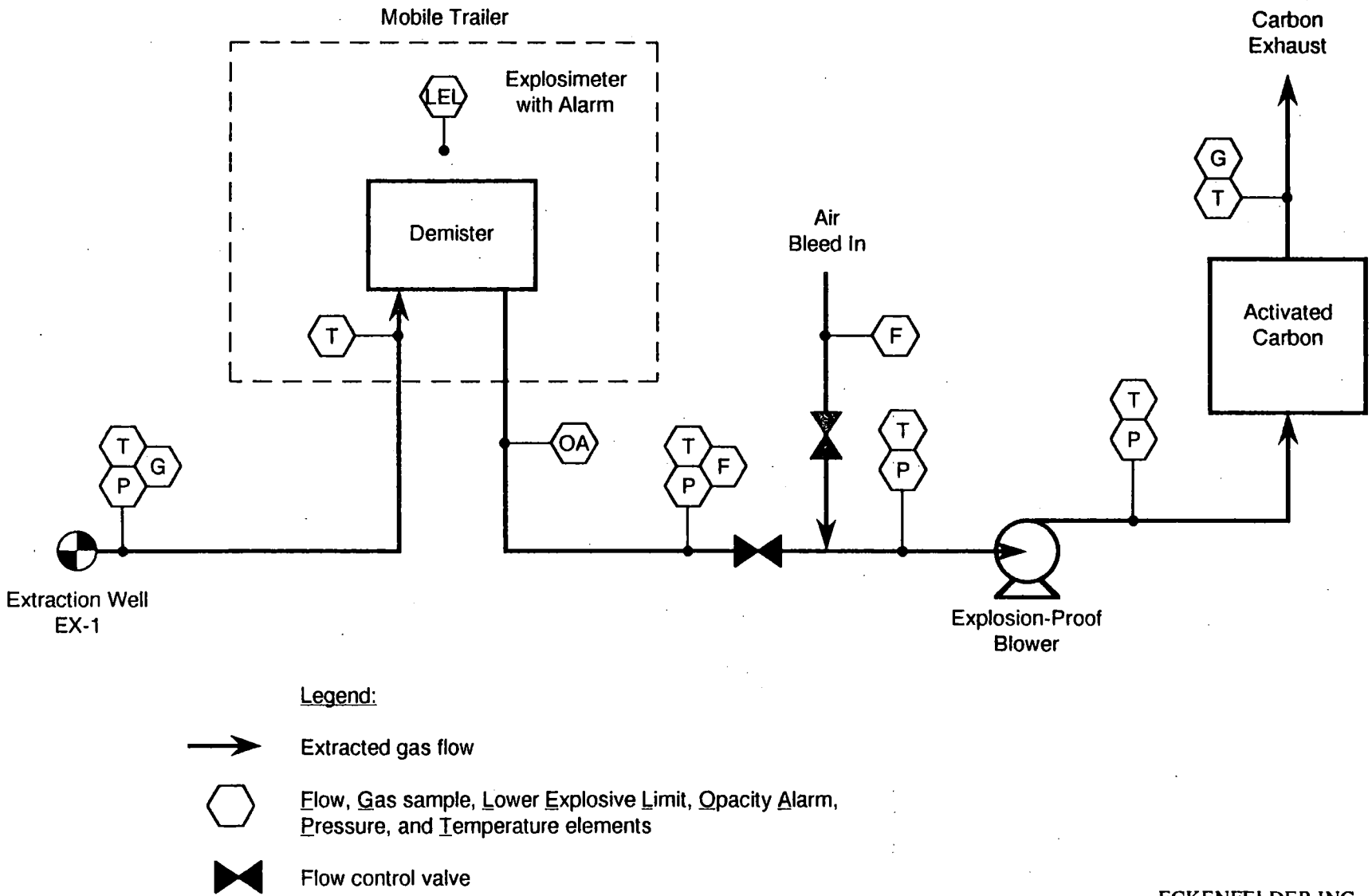


Figure 2-4. Pilot-Scale ISVS System Flow Diagram (Part 2 Testing)

gas dew point, a bed of granular activated carbon, and two blowers that can be operated independently, in parallel, or in series (see Figure 2-3). Instrumentation included sensors to measure flow, pressure/vacuum, and temperature of the gas stream. In addition, an opacity alarm and lower explosive limit (LEL) alarm were interlocked with the blowers to automatically shut the unit down if either smoke or a high LEL were encountered in the extracted gas .

For the Part 2 Testing, gases and vapors were extracted from the landfill at the extraction well and passed through the demister within the mobile trailer for removal of entrained water (see Figure 2-4). Vapors were then passed through an explosion-proof blower and a bed of granular activated carbon, both located outside the mobile trailer. The specific blower employed is a new addition to the pilot-scale unit that was added since the original work plan was prepared. The blower is of a non-sparking explosion-proof design, has a five horsepower explosion-proof electric motor and has a flow capacity of up to 225 standard cubic feet per minute (scfm). In addition, the blower is equipped with a Teflon® lip seal and an impregnated impeller housing to minimize gas leakage. The activated carbon unit used for all of the treatability testing was a Vapor Pac unit manufactured by Calgon Carbon Corp. The Vapor Pac unit was of polyethylene and PVC construction with a carbon steel frame. The unit had a flow capacity of 1,000 cfm (28.3 m^3/min) at a pressure drop of 30 in.W.C. and had a temperature rating of 150°F (65°C) maximum. The Vapor Pac unit was filled with in excess of 1,800 pounds (816 kg) of type BPL 6 x 16 granular activated carbon (by Calgon Carbon Corporation). The minimum carbon tetrachloride (CTC) adsorption rating of the carbon was 60 percent or greater. Figure 2-4 also shows the locations of all instrument measurement elements and gas sample ports as configured for the Part 2 Testing. The system was instrumented with pressure/vacuum sensors, flow meters (a rotameter for air bleed-in and a pitot tube for extracted gas), Type T thermocouples, an opacity alarm, and a LEL meter with alarm. The opacity and LEL alarms were both interlocked with the blower so that if either smoke is detected in the off-gas ducting or the trailer ambient LEL exceeds 20 percent, the blower would automatically shut down.

A slight modification was made to the pilot-scale ISVS system during the Part 2 Testing in order to inject air into the landfill for the pulse/slug tests. The modified pilot-scale system arrangement, shown in Figure 2-5, includes connection of an air-injection pipe from the blower outlet to the extraction well that permits introduction

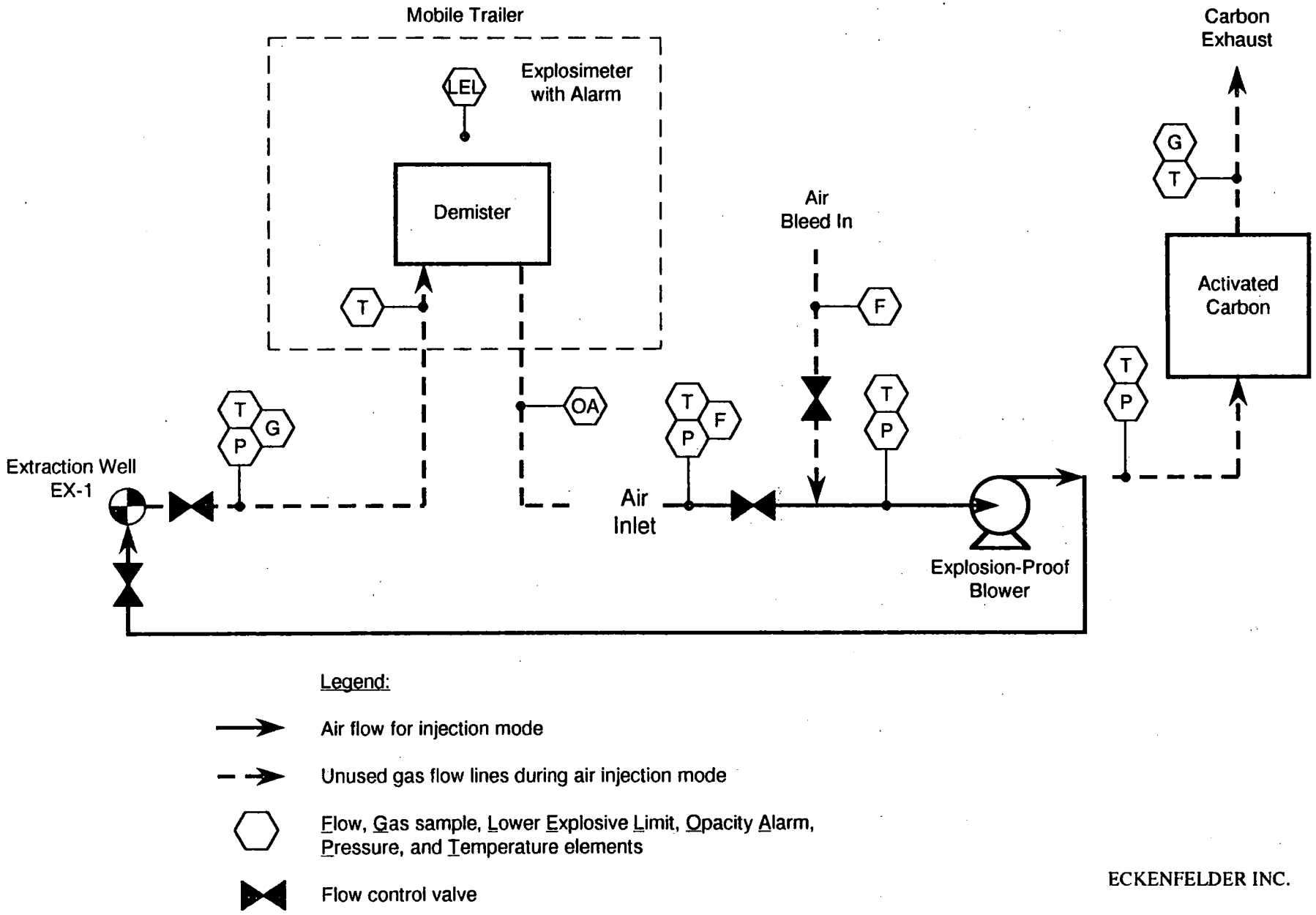


Figure 2-5. Pilot-Scale Pulse/Slug Test Air Injection Flow Diagram (Part 2 Testing)

of air into the landfill. Valves were added at the extraction well to permit rapid changeover from the air injection mode (Figure 2-5) to the ISVS mode (Figure 2-4). This changeover was required several times during the pulse/slug testing.

During operation of the mobile pilot-scale ISVS unit, two wastestreams are generated which require proper control. Figure 2-6 shows the streams associated with ISVS treatability testing. A gaseous exhaust stream which contains the stripped volatile constituents is treated by granular activated carbon. The spent carbon is tested and then is returned to the vendor for regeneration and reuse. A condensate stream is also generated (if the ambient temperature is less than the extracted gas temperature). The condensate requires sampling for VOCs and semi-volatile organic compounds (SVOCs) prior to proper disposal.

A portable ISVS unit designed by ECKENFELDER INC. was used for collecting vapor samples and for measuring pneumatic permeability at the sampling wells that had been previously installed in the toe of the landfill and the crested area to the southeast of the landfill. The portable ISVS unit is designed to provide an applied vacuum [up to 150 inches water column (in. W.C.)] to a sampling probe or well. Flows up to 10 cubic feet per minute (cfm) can be achieved with the internal vane-type vacuum pump. The entire unit weighs 140 pounds and is housed in a 2 foot by 1.5 foot by 1.5 foot shipping crate. The basic components of the system, including instrumentation and valving, are shown in Figure 2-7 and are listed as follows:

- Vacuum Pump
- Flow Meter
- Pump Inlet Vacuum Gauge
- Pump Outlet/Pressure Gauge
- In-stream Gas Monitoring System
- Flow-through Gas Sampling Valve Network
- Internal Tubing (Teflon® used for all gas sample collection)
- External Tubing (Teflon® used for all gas sample collection)
- Tubing Connectors
- Optional Activated Carbon Adsorber System
- In-stream Particulate Filter

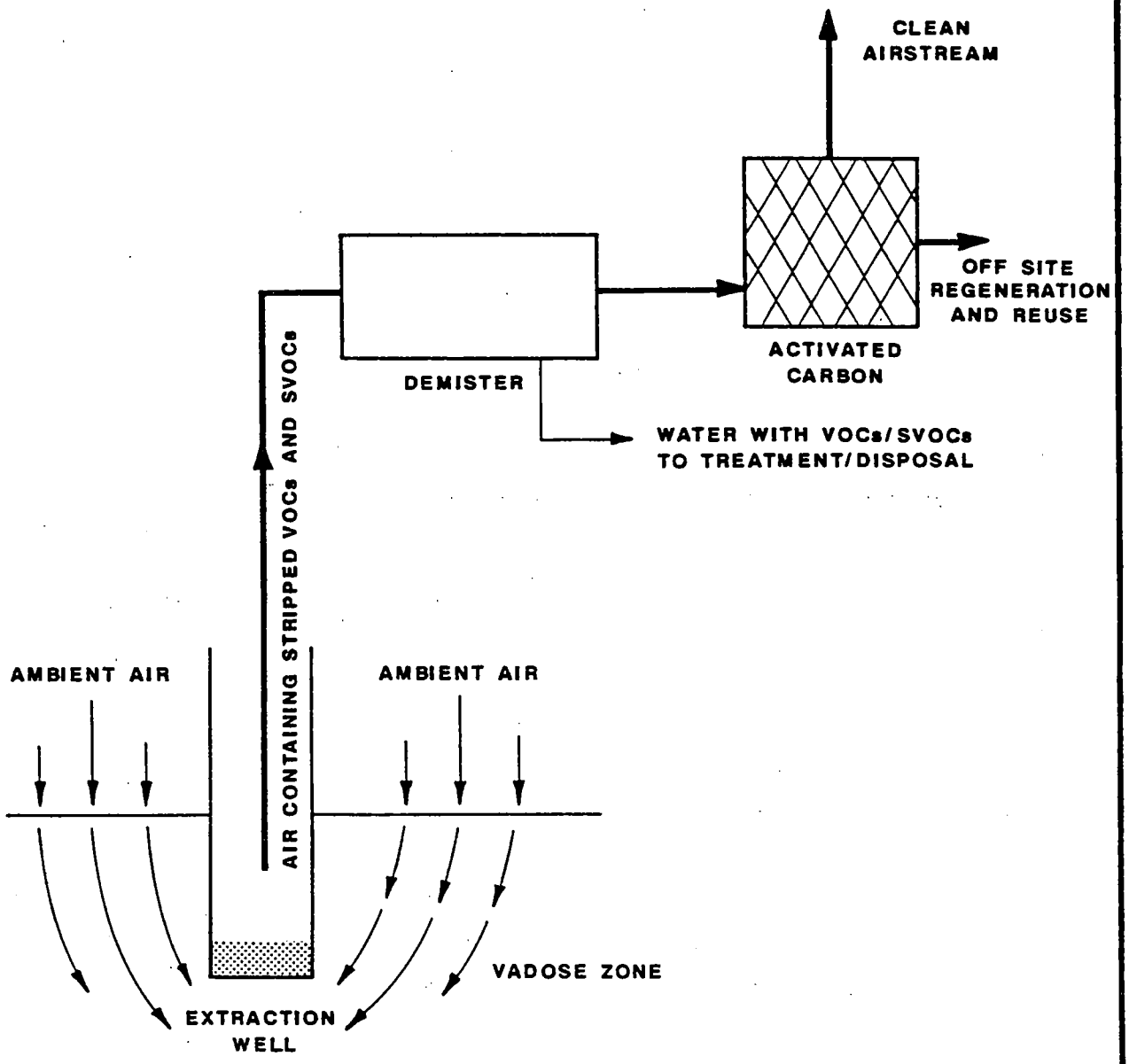
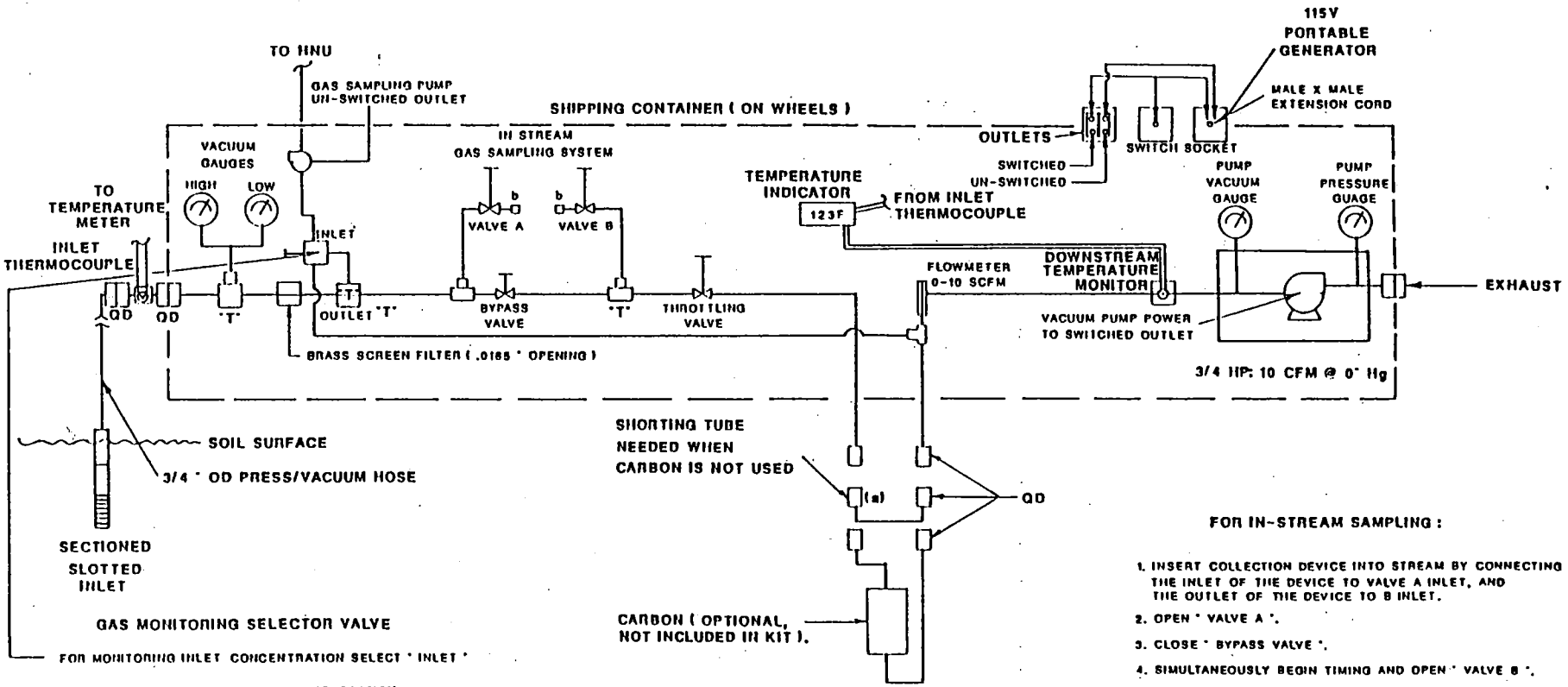


FIGURE 2-6
FLOW DIAGRAM OF INPUT, OUTPUT, AND SIDE STREAMS GENERATED DURING ISVS TREATABILITY TESTING

6595 3/91

ECKENFELDER INC. Nashville, Tennessee Mahwah, New Jersey



OD - QUICK DISCONNECT

(a) - FOR PLACING CARBON CANISTER IN SERIES

(b) - IN-STREAM SAMPLE COLLECTOR e.g. TENAX TRAP, CHARCOAL.

1. PERMANENT INTERNAL TUBING - TEFLON
2. STOPWATCH, BASIC TOOLS, CLEANING SUPPLIES, PORTABLE LAMP INCLUDED.

FIGURE 2-7

PROPRIETARY IN SITU VAPOR STRIPPING PORTABLE TEST UNIT

ECKENFELDER INC.
Nashville, Tennessee
Mahwah, New Jersey
Rochester, New York

The portable ISVS unit is very versatile in that a number of sampling devices can be employed (Tedlar® bags, sorbent tubes, locking gas syringes, canisters, etc.). Appendix B of the Work Plan contains a more detailed description of the components of the portable ISVS unit. The input and output streams for the portable unit are analogous (smaller volumes) to those described for the mobile pilot-scale ISVS unit. Activated carbon emission control was not required for the Lord-Shope toe and crest areas. There is no demister for the portable unit since it is only operated intermittently. Thus, there is no aqueous side stream generation. The portable ISVS unit was used to withdraw gas for sampling and/or monitoring purposes in the toe and crest areas.

The extraction well, used in conjunction with the mobile pilot-scale ISVS unit, is a vertical pipe constructed of 4-inch schedule (SCH) 40 PVC pipe with a screened bottom section. Extraction wells, monitoring probes, and passive vents used on the cap, toe, and crest consisted of 2-inch SCH 40 PVC pipe with screened bottom sections. The tops of the two monitoring probes on the cap and one of the passive vents were retrofitted with piping and instrumentation to permit gas monitoring, gas sampling with Tedlar® bags, pressure/vacuum measurements, and temperature measurements (see Figure 2-2). Pressure/vacuum measurements were taken with either manometers or gages that were attached to the extraction well, passive vents, and monitoring probes. Temperature measurements were taken with a hand-held digital thermometer which was attached to a thermocouple lead located near the bottom of the well at the different monitoring locations. At EX-1, a thermocouple was mounted in the 4 inch extraction pipe adjacent to the well. At the other locations (PV-2, EP-11, and EP-12) thermocouples were installed in the 2-inch PVC pipes at about 12 feet below grade level.

A diaphragm gas sampling pump equipped with an explosion-proof electric motor was used to withdraw gas for sampling and/or monitoring purposes from the monitoring probes, passive vents, extraction well, and carbon exhaust during both Part 1 and Part 2 Testing. The diaphragm gas sampling pump is equipped with a Teflon® sample tube, rotameter, vacuum gauge, sample port for Tedlar® bags, and a Tygon®[3] flex hose exhaust from which hand-held gas monitoring instruments draw their samples. All fittings were of brass with Teflon® tape for sealing

[3]Tygon® is a registered trademark of Norton Co.

threaded fittings. A portable generator was located on the cap area approximately 50 feet to the northwest of EP-11. The generator was used during Part 2 Testing to power the diaphragm gas sampling pump during gas monitoring and sampling operations, and to power temporary lights which were used on the cap area during night time sampling and data collection on the cap area. Power from the generator was supplied to each of the sampling locations (EX-1, EP-11, and EP-12) through ground fault intercept (GFI) circuits. Extension cords were equipped with explosion-proof connections at each of the sampling locations.

The hand-held gas monitoring instruments used during Part 1 Testing included an organic vapor analyzer (OVA) and an explosimeter. In addition, Draeger tubes specific for vinyl chloride and methane were used for qualitative soil gas monitoring. Hand-held gas monitoring instruments used during the Part 2 Testing included an OVA, a photoionization analyzer (referred to as an HNu), and an explosimeter.

The OVA used during the treatability tests was the Model OVA128 CENTURY organic vapor analyzer with the basic flame ionization detector configuration for monitoring total hydrocarbons. The OVA utilizes a hydrogen flame ionization detector that is calibrated with a methane standard and has a monitoring range of 0 to 1,000 ppm.

The instrument referred to as the HNu is a Trace Gas Analyzer, Model PI 101 by HNu Systems, Inc. It is equipped with an 11.7 eV lamp and is calibrated with an isobutylene standard. The HNu has a monitoring range of 0 to 2,000 ppm. The HNu will not response to methane gas, however, it sometimes will give false high readings if the gas being monitored has a high relative humidity (RH). High concentration of methane in the gas stream may reduce the HNu response.

The hand-held explosimeter is calibrated with a methane standard and has a monitoring range of 0 to 100 percent LEL.

2.4 SAMPLING AND ANALYSIS

The Sampling and Analysis Plan (SAP) presented here addresses only sampling and analysis of soil vapor collected in Tedlar® bags. This pilot-scale treatability study followed those components of the approved Quality Assurance Project Plan for the

Site (Lord Corporation, 1988) which do not address the sampling and analysis of the various media. Specifically, the components of the 1988 Plan which were followed include: maintenance of the chain-of-custody record, sample tags completion, and associated activities. The SAP created for this pilot-scale treatability study has its own quality assurance and quality control protocols and criteria reflecting the requirements of the gaseous medium.

2.4.1 Field Sampling Plan

The primary objective of the field sampling component of this treatability study was to obtain representative samples that would arrive at the analytical facilities intact. Because only VOCs and some SVOCs can be removed by vapor stripping, the samples were targeted for both quantitation and qualitation of their respective organic chemical content. All of the samples taken for chemical analyses during this study were soil gas collected in one (1) liter Tedlar® bags. It is through this information (in conjunction with additional hydrogeological and physical parameters) that the design of the ISVS approach for the remediation of landfill will be developed and finalized. The Tedlar® bag is outfitted with stainless steel and Teflon® fittings suitable for trace level organic analyses. (See Appendix D-7 of the Work Plan for the SOP for the Tedlar® bag usage). The portable ISVS unit was used to take all soil gas samples from the landfill during the Part 1 Testing and from the toe and crest areas; the diaphragm gas sampling pump was used to take all soil gas samples during the Part 2 Testing. The sampling protocol is provided in Appendix D-10 of the Work Plan. The Tedlar® bags were purged with prepurified nitrogen and had not been used in prior sampling programs.

Soil gas samples were taken at the previously installed wells at the toe of the landfill and the crested soil area. Samples were also taken during the various stages of testing at the landfill: the Part 1 Testing (a soil gas survey of the landfill), the 75-hour continuous ISVS test with passive vents closed, the 8-hour ISVS test with passive vents open, and the pulse/slug tests. All samples were collected in duplicate during Part 1 Testing. After the Part 1 Testing/analyses, it became evident that the "duplicate" precautions were not necessary for samples conveyed by ground transportation to the analytical laboratory. Those bags analyzed by more distant laboratories (i.e., QA/QC and methane analyses that required air transport to meet holding time requirements) were collected and shipped in duplicate.

Duplicate samples were not packaged in the same shipping container. This was done to help prevent loss of a sample through damage to the somewhat delicate Tedlar® bags. Samples were packaged in rigid plastic coolers with Styrofoam®[4] chips or plastic bubble-pack to absorb shock. This packaging protected the samples from sunlight, maintained the temperature at 25°C or less, and eliminated breakage due to shock. No cooling with blue ice was necessary per protocol.

The bags were shipped either over the road or by express carrier using only pressurized cargo holds. Arrangements were made with the receiving analytical laboratories so that the analyses could be performed immediately. There is a three day holding time for this type of sample per California Air Resources Division protocols. Weekend deliveries were made when needed if previous arrangements had been made with the laboratory. As indicated previously, the chain-of-custody procedures were followed and coolers were closed and sealed with security tape and chain-of-custody seals were applied. Detailed labeling of the individual sample bags was also performed.

The overall objective of the pilot-scale study was to obtain as much information about the site as possible relative to the implementation of the proposed ISVS technology. Another objective was to use the samples to assess the changes over time in chemical composition (quantity and quality) of the soil gas. The study was also used to determine the impact of the non-equilibrium mechanisms on remediation times/levels. The former objective was achieved by sampling at discrete intervals for a continuously operating system (portable and/or pilot-scale); the latter, by sampling (at predesignated times) the soil gas from the pulse/slug test. The specific sampling schedule for the 75-hour ISVS test is provided in Appendix C. The sampling schedules for the other tests are provided as appropriate in Section 3.0 of this report.

2.4.2 Quality Assurance/Quality Control Plan

The second component of the SAP details the quality assurance built into this study to provide reliable data. The objective of the Quality Assurance/Quality Control (QA/QC) Plan is both precision and accuracy of the data as well as

[4]Styrofoam® is a registered trademark of Dow Chemical Co.

representativeness, completeness, and comparability. As indicated previously, all samples were collected in duplicate in Part 1 Testing. The samples were not identified as duplicates so that the laboratory receiving shipment would not be able to determine which were the QA/QC samples. Instructions were included in each shipment indicating which of the bags were to be analyzed. It was critical, therefore, should any bag arrive damaged, that the Project Manager and field crew be notified immediately so that an appropriate backup sample could be analyzed in its place. A minimum of 10 percent blind duplicates from each sample group from each test at the landfill was taken. The 10 percent QA/QC level using blind duplicates was followed during Part 2 Testing also. For samples taken from the toe of the landfill and from the crested areas, another 10 percent were analyzed as duplicates. It is not known how well samples can be duplicated. Duplicate samples were collected immediately following each other. However, the sequence cannot actually be "immediate" in that it is our practice to purge the Tedlar® bag with at least two volumes of air from the soil gas stream prior to collecting the actual sample.

There were no field "spikes" performed. This reflects hesitancy to bring concentrated VOCs to the site as well as safety considerations for the field crews. Blind blanks, however, were sent to the laboratory for analysis. At least one blank/background per day of operation was taken and shipped for analysis. These were prepared on-site with ambient air using either the portable ISVS unit or the diaphragm gas sampling pump. Blank/background sampling was performed upwind of any other site activities.

It should be noted that selection of the analytical protocol(s) for the analysis of VOCs is not straightforward. Specifically, analyses of samples from Superfund sites usually follow USEPA SW846, Third Edition, Method 8240. However, this method is designated for water and non-aqueous materials. This latter category addresses soils, sludges, etc., but not gas. Indeed, special procedures/equipment are necessary to perform direct injection of vapors into the gas chromatograph with a mass spectrometer detector system, especially in achieving the introduction of internal standards.

USEPA Compendium Method TO-14 (USEPA, 1988), specially adapted for Tedlar® bag samples, was used for chemical-specific analyses for VOCs. The TO-14 method

was initially designed for SUMMA Passivated Canisters which use a "push" transfer mechanism for delivery to the GC. The Tedlar® bag requires a "pull" (extraction) transfer mechanism. Appendix C in the Work Plan is a summary of the method. The summary includes the reporting detection limits for the target compounds in ppb (vol/vol); the limits range from 2 to 8 ppb (v/v). Table 2-5 is a list of the VOCs that the soil gas was analyzed for by Method TO-14. Those VOCs indicated with an "X" are on the standard TO-14 volatile list. Approximately seven compounds that are specific to the Lord-Shope Landfill are not on the TO-14 list of analytes; these compounds were added to the menu of analytes prior to analysis. The minimum laboratory QA/QC requirements for Method TO-14 are also provided in the summary in Appendix C of the Work Plan.

Soil gas samples were also collected in Tedlar® bags taken for methane analysis. The samples were taken according to the sampling schedule in Appendix C of the Work Plan for the 75-hour ISVS test. The sampling schedules for methane for other tests are given as appropriate in Section 3.0 of this report. The same QA/QC procedures were followed for these samples as for the samples analyzed using a modified USEPA Compendium Method TO-14.

A minimum of 80 percent of all of the data was required to be valid by passing quality assurance testing in order to meet the quality objectives of the tests and be used in the mathematical modeling. An analytical result was considered valid if it had a reading above the limit of detection; if it was not found in a blank; or if it were in a blank, the concentration in the sample was more than five to ten times the quantity found in the blank; and if the laboratory QA/QC requirements had been met. (See Appendix C of the Work Plan for further information). A below method detection limit (BMDL) or not detected (ND) value was similarly considered valid if the same criteria (excluding the reading above the detection limit) were met. It should be noted that for those five common laboratory contaminants, a reported concentration was considered valid if the concentration in the sample was a minimum of ten times the concentration in the blank. These contaminants include acetone, methylethyl ketone, methylene chloride, phthalates, and hexane. Other materials found in the blank have a factor of five.

TABLE 2-5

LIST OF VOCs THAT SOIL GAS WAS ANALYZED FOR DURING THE TREATABILITY STUDY

VOCs	Standard in Method TO-14[a]
Benzene	X
Chlorobenzene	X
1,1-Dichloroethane	X
Tetrachloroethene (Tetrachloroethylene)	X
Toluene (Methyl Benzene)	X
trans-1,2-Dichloroethene	X
Trichloroethene (Trichloroethylene)	X
Vinyl chloride (Chloroethylene)	X
MEK (methyl ethyl ketone or 2-Butanone)	X
MIBK (methyl isobutyl ketone or 4-Methyl-2-pentanone)	
Acetone (Methylketone)	X
4-Methyl-2-pentanol (Methyl amyl alcohol)	
Cyclohexanone	
2-Butanol	
IPA (Isopropyl alcohol or 2-Propanol)	
Xylene (Dimethyl Benzene)	X
Chloroform (Trichloromethane)	X
Methylene chloride (Dichloromethane)	X
Methyl chloride (Chloromethane)	X
1,1,2,2-Tetrachloroethane	X
THF (Tetrahydrofuran)	X

[a]X" indicates that the compound is currently analyzed for by Method TO-14; procedure for analyses for other VOCs were developed under Method T0-14.

2.5 HEALTH AND SAFETY

A detailed Health and Safety Plan (HASP) was prepared and was included as an attachment to the Work Plan. The HASP was prepared consistent with the guidance provided in the USEPA Interim Final Document, "Guidance for Conducting Treatability Studies under CERCLA" (USEPA, 1989). The HASP, in conjunction with the treatability study, included contingency plans should there be an indication of fire or incipient fire within the landfill.

During work beyond the capped landfill, Level C personal protective equipment (PPE) was specified by the Lord Safety and Health Plan for the Lord-Shope site. As the liner and clay cap of the landfill were penetrated, Level B PPE was specified to be used until the level of airborne organic vapors could be determined. If the level of VOCs was below 50 ppm in the breathing zone after the liner and clay cap penetration activities, the PPE could be revised to Level C.

After Part 1 of the ISVS field testing was completed in November 1991, methane gas was identified in the landfill in concentrations ranging from 43 percent to 75 percent. Several modifications were made to the HASP to permit safe Part 2 Testing with the high methane gas concentration (ECKENFELDER INC., 1992). The following engineering and administrative controls were added to the HASP.

- Mobile pilot-scale ISVS unit was grounded.

- All gas piping upstream of the blower was maintained at a negative pressure during gas extraction operations. In this configuration any leakage would occur inward. The piping and connections internal to the trailer were of PVC.

- As a redundant backup, an explosimeter with alarm was used to monitor the ambient air inside the ISVS trailer. If, due to equipment failure, vapor escaped from the piping or moisture separator, the explosimeter would monitor the ambient VOC level. At 10 percent of the LEL, the "dead-man" system would shut the ISVS unit down, reducing the possibility of fire or explosion. (Note: the 10 percent limit in the original HASP was revised to

20 percent with the joint approval of the Lord Corporation and ECKENFELDER INC. project health and safety officers.)

- The blower was of a non-sparking explosion-proof design and had an explosion-proof electric motor.

- The only portion of the process piping that was under positive pressure was the discharge piping from the blower to the activated carbon unit. This portion of piping was located outside and away from the trailer (to the southeast which is the predominant downwind direction).

- The blower, metal off-gas piping, and activated carbon unit were appropriately grounded.

- There were no ignition sources (such as electrically operated sensors, etc.) inside the off-gas piping. Gas samples collected from piping between the extraction well and the blower required the use of an explosion-proof sampling pump. Slight modifications were made to the demister to prevent the possibility of combustible gases contacting the water drain portion of the system.

- In the event of a total power failure, all personnel would have been required to evacuate the trailer. Re-entry would have only been permitted after surveying with both a portable OVA and explosimeter. Health and safety equipment was stored outside the trailer so that it would be available in the event of a power outage.

- The off-gas piping between the blower and the carbon unit was surveyed with both a portable OVA and explosimeter to verify that no leaks were present after each system startup.

- A lock-out/tag-out procedure was established for working on electrical systems (such as the blower) within the ISVS mobile unit.

- Work areas were required to be lighted during night-time operations to at least the minimum illumination intensity of 5 foot candles. Temporary

lights were used to light the work area. Explosion proof flashlights were used near monitoring wells where the levels of methane may have been elevated. Temporary lights were used and were powered by a portable generator located at least 50 feet from the nearest monitoring point.

3.0 DESCRIPTION OF TREATABILITY STUDY

The components of the Treatability Study that are described here include site preparation, ISVS tests, pulse/slug tests, and toe and crest tests.

3.1 SITE PREPARATION

Site preparation consisted of the installation of an extraction well, passive vents, and monitoring probes as well as set-up of the ISVS test equipment.

3.1.1 Installation of Extraction Well, Vents, and Probes

The extraction well, EX-1, was installed according to the procedure described in Appendix D-4 of the Work Plan. This protocol includes not only the procedure for the installation of the well and appropriate screen packing, but also addresses the procedure whereby the breach of the cap was repaired (booted). The three passive vents (PV-1, PV-2, and PV-3) and two monitoring probes (EP-11 and EP-12) were also installed following the protocols given in Appendix D-4 of the Work Plan. Figure 2-2 shows the relative positions of the passive vents and monitoring probes to the extraction well. The rationale for installing both passive vents and monitoring probes was explained in Section 2.2.1. The extraction well was constructed of 4-inch SCH 40 PVC pipe and was 22 feet deep with the bottom four feet screened. The Work Plan had called for the well to be screened over its entire length and also proposed that the passive vents be approximately 20 feet deep, screened over their entire lengths; the monitoring probes were to be fully screened also. The passive vents and monitoring probes were constructed identically of 2-inch SCH 40 PVC pipe, 14 feet deep with the lower 4 feet screened. The positions, depth, and screening of the passive vents and monitoring probes were designed to provide a horizontal profile of the zone of influence of the extraction well. The final product was reviewed and approved (in writing) by a qualified hydrogeologist. Appendix D contains the boring logs for the wells/vents/probes that were installed.

3.1.2 ISVS Test Equipment Set-Up

The ISVS test equipment set-up for the Part 1 Testing was originally performed in November 1991. Once methane was determined to be present in high concentrations in the landfill, the necessary modifications were designed and the equipment set-up was modified in March 1992 to accommodate the methane (Part 2 Testing).

Equipment set-up for Part 1 Testing was initiated when the mobile ISVS trailer was transferred to the Lord-Shope Site. The trailer was positioned adjacent to the landfill to the southeast (see Figure 1-2), was appropriately blocked and leveled, and was wired for 440/480 AC. The granular activated carbon unit was delivered and positioned adjacent to the mobile process trailer and was piped into the process (between the demister and blowers). The blowers that are mounted inside the trailer were used during the Part 1 Testing (prior to the methane discovery). A schematic of the initial equipment set-up was shown previously as Figure 2-3. Next an operational status check was performed to make sure that all process systems and instruments were properly connected and operating. The appropriate calibration and/or calibration checks were performed on the gas monitoring instruments (OVA and explosimeter). Approximately 250 feet of 4-inch SCH 40 PVC piping was installed from the extraction well to the mobile ISVS trailer. Both an opacity alarm and LEL alarm were installed in the line and were interlocked with the blower to shut the process down if smoke or combustible gases were detected in the extracted gas and vapor stream.

Part 1 Testing was initiated at which time methane was encountered in the extracted soil/waste gas stream causing the pilot-scale ISVS system to automatically shut down. The process was reconfigured with the addition of an explosion-proof blower and several other safety-related changes. The revised system was set up according to the flow diagram shown previously in Figure 2-4 (refer to Section 2.3 for additional detail). The blower was skid-mounted outside the process trailer and the carbon was placed on the outlet side of the blower away from the trailer to the southeast as specified by the revised HASP. This blower/carbon configuration was chosen to take advantage of the adiabatic heat of compression of the blower. The gas was heated as it was compressed by the blower, thereby reducing the relative humidity (RH) of the gas from almost 100 percent to approximately 50 percent or

less. The capacity of the carbon to retain VOCs can be greatly reduced if the RH is too high. This blower/carbon configuration also allowed the existing gas heat exchanger system within the mobile unit to be bypassed. The heat exchanger system was difficult to control and maintain and also somewhat restricted the gas flow rate.

Minor process piping changes were required to complete the pulse/slug tests. These changes are described in detail in Section 3.3.1.

3.2 ISVS TESTS

This section contains descriptions of the 75-hour ISVS test, the 8-hour passive vent test, and the associated equipment and data collection for the tests.

3.2.1 Process Configuration, Equipment, and Instrumentation

The 75-hour ISVS test and the 8-hour passive vent test were both conducted using the same process configuration as previously illustrated in Figure 2-3 and described in Sections 2.3 and 3.1. In this configuration, gases and vapors were drawn from the extraction well, passed through the off-gas line to the demister within the ISVS trailer, then drawn back outside the trailer to the explosion-proof blower, and finally to the activated carbon unit for VOC removal. Figure 2-2 shows the sampling and instrumentation used on the cap for the pilot-scale ISVS testing. Temperature elements, pressure elements, and gas sampling ports were located on the extraction well EX-1, passive vent PV-2, and monitoring probes EP-11 and EP-12. The three passive vents (PV-1, PV-2, and PV-3 in Figure 2-2) were sealed closed during the 75-hour ISVS test and were opened to allow air introduction into the landfill during the 8-hour passive vent test. All other instrumentation used for the two tests was identical. The temperature and vacuum measurements at passive vent PV-2 were not taken during the 8-hour passive vent test since PV-2 was opened to ambient conditions.

3.2.2 Data Collection

Both process data and soil/waste gas data were collected during the ISVS tests.

3.2.2.1 Process Data. Process data were recorded on data sheets and in the site field log book during operation of the pilot-scale ISVS system. Data sheets within the Work Plan were planned to be used during the Part 1 Testing; however, the almost instantaneous automatic shutdown of the process due to methane gas precluded the use of these data sheets.

A new data sheet was developed for recording data at the mobile pilot-scale ISVS unit during the Part 2 Testing (Figure 3-1). The data collected by direct reading included: the trailer ambient LEL and temperature; barometric pressure; demister inlet vacuum and temperature; pitot tube vacuum, temperature, and differential pressure; blower inlet vacuum and temperature; blower discharge pressure and temperature; carbon discharge temperature; and the air bleed-in flow rate. The pitot tube differential pressure was not shown on the data sheet, but was recorded adjacent to the pitot tube vacuum entry. The air bleed-in flow rate was read directly from a rotameter that was calibrated for air flow rate. The extracted gas flow rate was calculated from the pitot tube data, barometric pressure, and the gas specific gravity according to the following equation:

$$Q = 128.8 \times K \times D^2 \times \sqrt{\frac{P \times \Delta P}{(T + 460) \times S_s}}$$

where:

- Q = gas flow rate [standard cubic feet per minute (scfm)]
- K = 0.556 flow coefficient for 1-1/2-inch SCH 40 pipe
- D = 1.610 inches (inside diameter of pipe)
- P = static line pressure [pounds per square inch absolute (psia)]
- ΔP = pitot tube differential pressure [inches water column (in W.C.)]
- T = temperature (°F)
- S_s = gas specific gravity at 60°F

Substituting in the known values for K and D, the equation becomes:

$$Q = 185.6 \times \sqrt{\frac{P \times \Delta P}{(T + 460) \times S_s}}$$

The static line pressure, P, was calculated by subtracting the pitot tube vacuum from the barometric pressure. The gas specific gravity, S_s, was estimated during

ISVS Mobile Unit Data Sheet
LORD-SHOPE TREATABILITY STUDY

Page ____ of ____

ORIGINAL (Red)

	Date:								
	Time:								
	By:								
	Units								
Explosimeter:									
Trailer Ambient	% LEL								
Pressure/Vacuum:									
Barometric	in. Hg.								
Demister Inlet	in.W.C.								
Pitot Tube	in.W.C.								
Blower Inlet	in.W.C.								
Blower Discharge	in.W.C.								
Temperature:									
Ambient Air	°C								
Demister Inlet	°C								
Pitot Tube	°C								
Blower Inlet	°C								
Blower Discharge	°C								
Carbon Discharge	°C								
Flow (direct & calculated):									
Air Bleed In	scfm								
Extracted Gas	scfm								
HNu Gas Monitoring:									
Demister Inlet	ppm								
Blower Discharge	ppm								
Carbon Discharge	ppm								
OVA Gas Monitoring:									
Demister Inlet	ppm								
Blower Discharge	ppm								
Carbon Discharge	ppm								
Chem. Spec. Gas Samples:									
Demister Inlet	smpl #								
Blower Discharge	smpl #								
Carbon Discharge	smpl #								
Methane Gas Samples:									
Demister Inlet	smpl #								
Blower Discharge	smpl #								
Carbon Discharge	smpl #								

Comments: _____

_____

_____

_____

_____

_____ Reviewed by: _____ Date: _____

Figure 3-1. Pilot-Scale ISVS Data Sheet Used for Part 2 Testing

the pilot-scale ISVS testing and was used in the above equation so that an approximate gas flow rate, Q, could be calculated.

Once the methane results were obtained for the gas sample, S_s was calculated and the extracted gas flow rate, Q, was recalculated. Additional information on the pitot tube flow sensor and calculation of flow rate is presented in Appendix E.

The data sheet (Figure 3-1) has places for gas monitoring and gas sampling data entry, however these data were actually recorded in the site field log book along with vacuum, temperature, gas monitoring, and gas sampling data from the landfill cap area. (Refer to Figure 2-2 for the data collection locations on the cap.)

During both the 75-hour ISVS test and the 8-hour passive vent test, the gas flow rate was initially set at 50 scfm and was subsequently stepped up. A complete set of data was taken at or near the times of startup and each time the flow rate was increased. Data was taken at approximately 15 minute intervals for an hour following each flow rate change and then once hourly as long as the site was manned by ECKENFELDER INC. personnel during each test. After the first 24 hours of the 75-hour ISVS test, the system was allowed to operate for periods in an unmanned mode, and data were not collected during those periods. The 8-hour passive vent test was operated with ECKENFELDER INC. personnel on site during the entire test period.

3.2.2.2 Soil Gas Data. Soil gas data were collected during the 75-hour ISVS test and the 8-hour passive vent test using the diaphragm gas sampling pump and hand-held monitoring instruments (OVA, HNu, and explosimeter). The diaphragm gas sampling pump was used to collect all soil gas samples in one liter Tedlar® bags according to the SOP in Appendix F. Each of the hand-held monitoring instruments has an intrinsic air delivery system which can be used to monitor the soil gas from the exhaust of the diaphragm gas sampling pump. Further details about the diaphragm gas sampling pump and hand-held monitoring instruments are provided in Section 2.3 The hand-held monitoring instruments were either calibrated or a calibration check was performed each day prior to use according to procedures outlined in the operator's manual for each instrument.

The results of each calibration or calibration check were noted in the site field log book each day the instruments were used. Sampling times, sample numbers for Tedlar® bag samples, and all soil gas monitoring data were also recorded in the site field log book.

Soil gas data were collected during the 75-hour ISVS test at scheduled intervals on the landfill cap at the extraction well (EX-1) and the two monitoring probes (EP-11 and EP-12). Soil gas data were also collected at the carbon exhaust at the mobile pilot-scale ISVS unit. (See Figures 2-2 and 2-4 for these gas sampling locations.) Table 3-1 gives a summary of the sampling and analysis plan for the chemical specific analyses (CSA) of soil gas for VOCs and methane for the 75-hour ISVS test. The menu of VOCs that the soil gas was analyzed for is provided in Table 2-3. Due to the discovery of methane in the landfill soil gas during the Part 1 Testing, additional soil gas samples were collected for methane analysis during Part 2 Testing; this was an addition to the analyses specified in the Work Plan. Monitoring data were recorded each time specific samples were collected. Lord Corporation provided analytical services for the primary analysis of samples for VOCs; Ross Analytical Services, Inc., Strongsville, Ohio provided outside QA/QC for the VOC analysis. Methane analysis was performed by Twin City Testing Corporation, St. Paul, Minnesota. Although the Work Plan specifies that back-up samples should be taken for all samples collected for chemical specific analysis, it was decided that back-ups would only be collected for samples used as outside QA/QC for VOC analysis and for samples used for methane analysis. (See Section 2.4 of this report for the QA/QC requirements.) This decision reflected the Part 1 Testing experiences where no back-up samples were required by the Lord Corporation laboratory to perform the VOC analyses. The samples were tranported daily by ground transportation to the Lord Corporation Laboratory which was less than a half-hour from the site. As such, there was no impact on sample integrity resulting from handling during commercial shipment or pressure variations experienced in air borne express shipment. This eliminated the need for back-up samples. This decision did not impact the duplicate samples taken for QA/QC purposes.

Samples sent to Ross Analytical Services, Inc. and Twin City Testing Corporation were packaged in rigid plastic coolers in Styrofoam® packing material or plastic bubble pack. Back-up samples were shipped in separate containers according to specifications in Section 2.4.

TABLE 3-1

SUMMARY OF SAMPLING AND ANALYSIS PLAN FOR 75-HOUR ISVS TEST

Day	Approximate Sampling Period	Sample Location				Daily Total of Samples
		EX1	Carbon Exhaust	EP11	EP 12	
SUMMARY OF SAMPLES FOR VOC CHEMICAL SPECIFIC ANALYSIS (PRIMARY LABORATORY[a])						
1	(noon-midnight)	14	3	1	2	20
2	(midnight-8 p.m.)	3	1	1	2	7
3	(8 a.m.-8 p.m.)	2	1	--	1	4
4	(8 a.m.-8 p.m.)	2	1	--	1	4
5	(8 a.m.-noon)	2	2	1	2	7
Subtotal of Tedlar® bag samples						42
QA/QC (internal - 1 bag/sample for 6 samples)						6
QA/QC (external[b] - 2 bags/sample for 3 samples)						6
Total Samples for Chemical Specific Analysis						54
SUMMMARY OF SAMPLES FOR METHANE ANALYSIS[c] (2 bags/sample)						
1	(noon-midnight)	3	2	1	1	14
2	(midnight-8 p.m.)	2	1	--	--	6
3	(8 a.m.-8 p.m.)	1	1	--	--	4
4	(8 a.m.-8 p.m.)	1	1	--	1	6
5	(8 a.m.-noon)	2	1	1	1	10
Subtotal of Tedlar® bag samples						40
2 QA/QC (interm - 2 bags/sample for 2 samples)						4
Total Samples for Methane Analysis						44
GRAND TOTAL OF SAMPLES TAKEN FOR ANALYSIS						98

[a]Lord Corporation Laboratory.
[b]Performed by Ross Analytical Services, Inc.
[c]Performed by Twin City Testing Corporation.

There were two changes to the sampling plan in Table 3-1. An additional set of soil gas data was taken at EX-1, EP-11, and EP-12 immediately before the start of the test to provide time-zero data. Also, five samples were collected for VOC analysis for internal QA/QC, and two background ambient air samples were taken in addition to those listed. The specific times during the 75-hour test when soil gas data were collected are provided in Section 4.1.2.

Soil gas data (soil gas samples and monitoring data) were collected during the 8-hour passive vent test on the landfill cap at the extraction well, EX-1, and at the carbon exhaust at the pilot-scale ISVS unit (Figures 2-2 and 2-4 provide these gas sampling locations). Soil gas data were not collected at the monitoring probes on the cap. Three samples were collected for VOC analysis at EX-1; one sample was collected for methane analysis at the carbon exhaust. All samples were taken in duplicate and shipped according to the same procedures used for the 75-hour test. The three samples collected at EX-1 were taken after each change in extracted gas flow rate. (See Section 3.2.4 for these intervals.) No outside QA/QC was performed for this set of samples. All sampling data were recorded in the site field log book; specific sampling times and data collected during the 8-hour passive vent test are given in Section 4.2.2.

3.2.3 Description of 75-Hour ISVS Test

The original Work Plan called for operating the ISVS system for four days (96 hours) with passive vents either closed or opened, depending on the results of gas flow tests at the extraction well. The gas flow tests were not conducted because of the high methane concentration which caused the system to automatically shut down (Part 1 Testing). Therefore, it was decided to conduct a three-day ISVS test with the passive vents closed followed by an 8-hour test with the passive vents opened (Part 2 Testing).

The three-day ISVS test actually had a duration of 75 hours and was conducted at three target gas flow rates. The target flow rates were 50 scfm for the first 5.5 hours; 100 scfm for the next 15.25 hours; and the maximum achievable flow rate for the balance of the 75-hour test. The target flow rates were calculated during the test using a gas specific gravity of 0.711 (assuming 65 percent methane in air). The

actual flow rates were not calculated until after completion of the 75-hour test when the methane analytical data were available. The actual measured methane concentrations in the extracted gas were less than 50 percent and decreased with run time (as is discussed in detail in Section 4.1.2.1). Because of this, the gas specific gravity was closer to 1.0 and the actual gas flows were, in general, below the target flow rates. Process data and soil gas data were collected throughout the 75-hour ISVS test as previously described in Section 3.2.2.

3.2.4 Description of 8-Hour Passive Vent Test

Upon completion of the 75-hour ISVS test, the three passive vents (PV-1, PV-2, and PV-3) were opened to the atmosphere and the 8-hour passive vent test was conducted. Three target flow rates were also used for the ISVS passive vent test: 50 scfm for the initial 2 hours; 100 scfm for the next 3 hours; and the maximum achievable flow rate for the duration of the test. Although the test is referred to as the 8-hour passive vent test, the actual test duration was 7.4 hours. The flow, pressures, and temperatures appeared to be at steady state so the test was discontinued at 7.4 hours run time.

Process data were taken identical to those taken during the 75-hour test with the exception of passive vent PV-2 temperature and pressure data which were not taken because PV-2 was opened to the atmosphere. Process data and gas sample data were collected during the passive vent test as previously described in Section 3.2.2.

3.3 PULSE/SLUG TESTS

This section contains descriptions of the pulse/slug tests and the associated equipment and data collection for these tests.

3.3.1 Process Configuration, Equipment, and Instrumentation

Two different process configurations were necessary for the pulse/slug tests. The configuration shown in Figure 2-5 was used to inject a given volume or slug of air into the landfill via the extraction well EX-1. For the air injection configuration, a 2-inch diameter polyethylene flex hose was connected from the discharge side of the explosion-proof blower to EX-1. The piping connection at EX-1 was modified with

the addition of two gate valves to permit quick changeover from the air injection mode to the gas and vapor extraction mode. Piping at the explosion-proof blower was reconnected each time the changeover was required.

3.3.2 Data Collection

Both process data and soil gas data were collected during the pulse/slug tests.

3.3.2.1 Process Data. Process data that were taken during the pulse/slug tests were limited compared to that taken for the 75-hour and 8-hour ISVS tests. Since the pulse/slug tests involved injection of a given air volume followed by a waiting period and then extraction with gas sampling at specified volumes, the data critical to these tests were those needed to calculate off-gas flow rate. As such, data that were collected at the mobile pilot-scale trailer location were barometric pressure and the pressure, temperature, and differential pressure, and pilot tube. These data were taken at approximately 15-minute intervals during the air injection cycle and at 5 to 10-minute intervals during the extraction mode. The data sheet shown in Figure 3-1 was used to record the data.

3.3.2.2 Soil Gas Data. Soil gas data were collected using the diaphragm gas sampling pump and hand-held monitoring instruments (OVA, HNu, and Explosimeter) by the same methods described in Section 3.2.2.2. All soil gas samples were collected in one liter Tedlar® bags using the diaphragm gas sampling pump; monitoring data were collected from the exhaust of the diaphragm gas sampling pump using the hand-held monitoring instruments. Further detail about these instruments is provided in Section 2.3. Soil gas data were collected on the landfill cap at the extraction well, EX-1.

Table 3-2 provides a summary of the sampling and analysis plan for the CSA of the soil gas for VOCs and methane. Monitoring data were collected each time a Tedlar® bag sample was collected. The same laboratories were used for CSA as for the 75-hour ISVS test and the 8-hour passive vent test. The QA/QC plan was followed as given in Table 3-2. The sampling intervals of extracted gas for each test were designated according to the percent volume of injected air that had been extracted, i.e., at 10 percent and 25 percent of the injected volume. The actual sampling times and corresponding gas volume percentages are reported in Section 4.3.2. Although

TABLE 3-2

SUMMARY OF SAMPLING AND ANALYSIS PLAN FOR PULSE/SLUG TESTS

Injected Air Residence Time	Samples 10% volume	Samples 25% volume	Daily Total of Samples
SUMMARY OF SAMPLES FOR VOC CHEMICAL SPECIFIC ANALYSIS (PRIMARY LABORATORY[a])			
1 hr	1	1	2
1 hr	1	1	2
1 hr	1	1	2
5 hr	1	1	2
15 hr	1	1	2
Subtotal of Tedlar® Bag Samples			10
QA/QC (internal - 1 bag/sample for 2 samples)			2
QA/QC (external[b] - 2 bags/sample for 1 sample)			2
Total Samples for Chemical Specific Analysis			14
SUMMARY OF SAMPLES FOR METHANE ANALYSIS[c] (2 bags/sample)			
1 hr	--	--	--
1 hr	1	1	4
1 hr	1	1	4
5 hr	1	1	4
15 hr	1	1	4
Subtotal of Tedlar® Bag Samples			16
QA/QC (internal - 2 samples at 2 bags/sample)			4
Total Samples for Methane Analysis			20
GRAND TOTAL SAMPLES FOR ANALYSIS			34

[a]Lord Corporation Laboratory.
[b]Performed by Ross Analytical Services, Inc.
[c]Performed by Twin City Testing Corporation.

the Work Plan specifies that back-up samples should be taken for all samples, it was decided that back-ups would be taken only for samples collected for outside QA/QC for VOC analysis and for samples for methane analysis as previously discussed (see Section 3.2.2.2). In order to obtain the most complete set of data possible, time-zero soil gas samples were taken in duplicate for VOC analysis immediately after the ambient air was injected for the 5-hour and 15-hour tests. These samples, collected for time-zero data, were taken in addition to the samples called for in the Work Plan. All sampling data were recorded in the dated and signed site field log book and are reported in Section 4.3.2.

3.3.3 Description of Pulse/Slug Tests

After the 8-hour passive vent test was completed, the passive vents were closed and changes to equipment were made so that the pulse/slug tests could be performed. These changes are given in Section 3.3.1. Five pulse/slug tests were performed, each with a target volume of 2,500 ft^3 ambient air to be injected. In the first three tests, the injected air had a 1-hour residence time before it was extracted. The fourth test had a 5-hour residence time for the injected air; the last test employed a 15-hour residence time. The volume of ambient air was calculated by multiplying the ambient air flow rate by the injection time. After each prescribed residence time, the soil gas was extracted from the extraction well, EX-1. Soil gas extraction was ended for each test after soil gas data had been collected per the schedule in Section 3.3.2.2. Process data for each test was taken as described in Section 3.3.2.1.

3.4 TOE AND CREST TESTING

This section contains descriptions of the testing performed at the toe and crest areas of the landfill and the associated equipment and data collection.

3.4.1 Process Configuration, Equipment, and Instrumentation

The portable ISVS unit was used for testing of the soil at the toe and crest areas. The portable ISVS unit was powered by the gas generator and used without modification to the design described in Section 2.3. The portable ISVS unit was attached to the 2 inch PVC pipe at each toe and crest well by a hose with a PVC adapter; the connection at the well was sealed with duct tape. A Type

T thermocouple was inserted into the test wellhead for temperature measurements with the hand-held temperature reading device during the testing for the determination of pneumatic permeability. During parts of the testing, a U-tube manometer was used to monitor the vacuum change in an adjacent well. Hand-held monitoring instruments (OVA, HNu, and explosimeter) were used to monitor the exhaust from the portable ISVS unit during Part 1 Testing and Part 2 Testing. Draeger tubes specific for vinyl chloride and methane were used during Part 1 Testing. During Part 2 Testing, Draeger tubes were not used based on results from Part 1 Tests.

3.4.2 Data Collection

Both process data and soil gas data were collected during the toe and crest testing.

3.4.2.1 Process Data. Process data were recorded in the site field log book for all toe and crest testing. The data sheet for the portable ISVS unit given in the Work Plan (page 7-7) was not used. Process data collected by direct reading were pump inlet vacuum, pump outlet pressure, soil gas flow rate, and temperature. Manometer readings were also recorded when manometers were used.

3.4.2.2 Soil Gas Data. Soil gas data were collected using the portable ISVS unit and hand-held monitoring instruments (OVA, HNu, and Explosimeter). During the testing on November 13 and 14, 1991, soil gas samples were collected in one liter Tedlar® bags from each well on each day. All samples were collected in duplicate and were sent to Lord Corporation Laboratory for analysis for VOCs (see Table 2-3 for the menu of compounds). For each well, on day one of the testing, one sample was collected after approximately one minute of operation, then a second sample was collected from each well after 15 to 30 minutes. One sample was collected from each well after 15 to 30 minutes of operation on the second day of testing. Soil gas monitoring data were collected using Draeger tubes specific to methane and vinyl chloride, an OVA, and an explosimeter during the two days of testing in November.

Three duplicate QA/QC samples were collected; one ambient background sample was collected. A total of 28 samples were collected during the November testing. No outside QA/QC was performed for these samples. During the pneumatic permeability testing, soil gas monitoring data were collected using the OVA, HNu,

and explosimeter. All soil gas data (i.e., monitoring data, sampling times, and sample numbers) were entered into the site field log book and are reported in Section 4.4.

3.4.3 Description of Toe and Crest Tests

On November 13 and 14, 1991, the eight wells on the toe and crest areas were tested for the presence of any standing water and were developed using the portable ISVS unit. Soil gas samples for CSA for VOCs were collected from each well; two samples were collected on November 13 from each well, and one sample was collected on November 14 from each well. Process data were collected as described in Section 2.4.2.1 and specific soil gas sampling and monitoring were performed as stated in Section 2.4.2.2. Adjacent wells were also monitored with a manometer for vacuum development during the test.

The testing was repeated on March 30 and 31, 1992. Each well was tested for 15 to 35 minutes and only process and soil gas monitoring data were collected. These tests were conducted by operating the portable ISVS unit at three different flow rates and by monitoring the process data. For some wells, it was impossible to use three flow rates because of the high inlet vacua that were measured. The data from these tests were used to calculate the pneumatic permeability of the soil in the toe and crest areas. All data are presented in Section 4.4. (Note that the data generated by the November testing were presented in the interim report of January 22, 1992, included as Appendix B.)

TABLE 4-1

PROCESS DATA *MEASURED* DURING 75-HOUR ISVS TEST

Parameter	Units
Parameters Measured at Mobile ISVS Unit	
Combustible Gas, Trailer Ambient	% LEL
Pressure	
Barometric	mm Hg
Pitot Tube	in.W.C.[a]
Vacuum	in.W.C.
Pitot Tube	in.W.C.
Blower Inlet	in.W.C.
Temperature	
Ambient Air	°C
Demister Inlet	°C
Pitot Tube	°C
Blower Inlet	°C
Blower Discharge	°C
Carbon Discharge	°C
Flow Rate, Air Bleed-in	scfm[b]
Parameters Measured at Extraction Well (EX-1), Passive Vent 2 (PV-2), and Monitoring Probes (EP-11 and EP-12)	
Vacuum	in.W.C.
Temperature	°C

[a]Inches water column (406.8 inches of water column equals 1 atmosphere).
[b]Standard cubic feet per minute (adjusted to 20°C [68°F] and one atmosphere pressure).

the 75-hour test for the various locations. A computer-generated table, or spreadsheet, with all process data collected from each location is given as Appendix G; a similar spreadsheet is included as Appendix H for the field monitoring data collected during this test. These spreadsheets contain the date, time, and location of data recording, as well as the calculated parameters. Table 4-2 lists the parameters calculated from the process data that were recorded. The results presented in this section are from the data in the spreadsheets. The calculated flow rate and volume data are presented first. Vacuum, pressure, and temperature data are presented next. The field monitoring data pertaining to chemical monitoring are discussed in Section 4.1.2.1.

4.1.1.1 Flow Rate and Volume Data. The extracted gas flow rate was calculated using the equation given in Section 3.3.2.1 with the appropriate pitot tube data presented in Appendix G. Figure 4-1 shows the extracted gas flow rate in standard m^3/min (std m^3/min) and scfm as a function of testing time. Because ambient bleed-in air was introduced in the extraction gas upstream of the blower (downstream of the extraction well) to meet the minimum flow requirement of the blower, it was necessary to calculate the total gas flow rate through the blower and carbon unit by summing the two flow rates. Figure 4-2 shows the total flow rate through the blower and carbon unit as well as the extracted gas and air bleed-in flow rates for the 75-hour test as a function of run time. Gas was extracted from the landfill at a flow rate of approximately 50 scfm for the first 6 hours of the test. The flow rate of the extracted gas was then increased to approximately 90 scfm (the target was 100 scfm) and gradually tapered off to 60 scfm between the run times of 7 hours and 21 hours. This gradual decline in extracted gas flow rate occurred as the air bleed-in flow rate was adjusted to maintain a flow rate of 90 to 95 scfm through the blower. Two other factors contributed to the flow rate decline: 1) during this time the vacuum within the landfill was increasing, reflecting the gas flow resistance; and 2) the methane content in the gas stream was decreasing, which increased gas density and reduced the flow rate (at a given pitot tube reading). At approximately 21 hours into the test, the air bleed-in flow rate was reduced to zero, and a maximum flow rate was achieved for the gas from the landfill. This flow rate ranged from 68 to 82 scfm for the duration of the test. This was less than the 90 scfm achieved at about 7 hours run time for the reasons previously indicated.

TABLE 4-2

PROCESS DATA *CALCULATED* FOR 75-HOUR ISVS TEST

Parameter	Units
Flow Rate	
Extracted Gas	scfm and std m^3/min
Air Bleed-in	scfm and std m^3/min
Total (sum of extracted gas and air bleed-in)	scfm and std m^3/min
Volume	
Extracted Gas	std ft^3 and std m^3
Air Bleed-in	std ft^3 and std m^3
Total (sum of extracted gas and air bleed-in)	std ft^3 and std m^3
Pressure	
Carbon Unit Differential	psia
Absolute Ambient	psia
Blower Differential	in.W.C.
Pitot tube, Absolute	mmHg
Blower Discharge, Absolute	mmHg
Vacuum	
Blower Inlet	psi
Other	
Extracted Gas Specific Gravity	unitless, referenced to air
Relative Humidity	% RH
Blower Differential Temperature	°C
H2O Saturation of Gas at Pitot Tube	mmHg
H2O Saturation of Gas at Blower Discharge	mmHg

Std = standard (flow or volume adjusted to standard conditions of 20°C [68°F] and one atmosphere pressure).
psia = pounds per square inch, absolute.

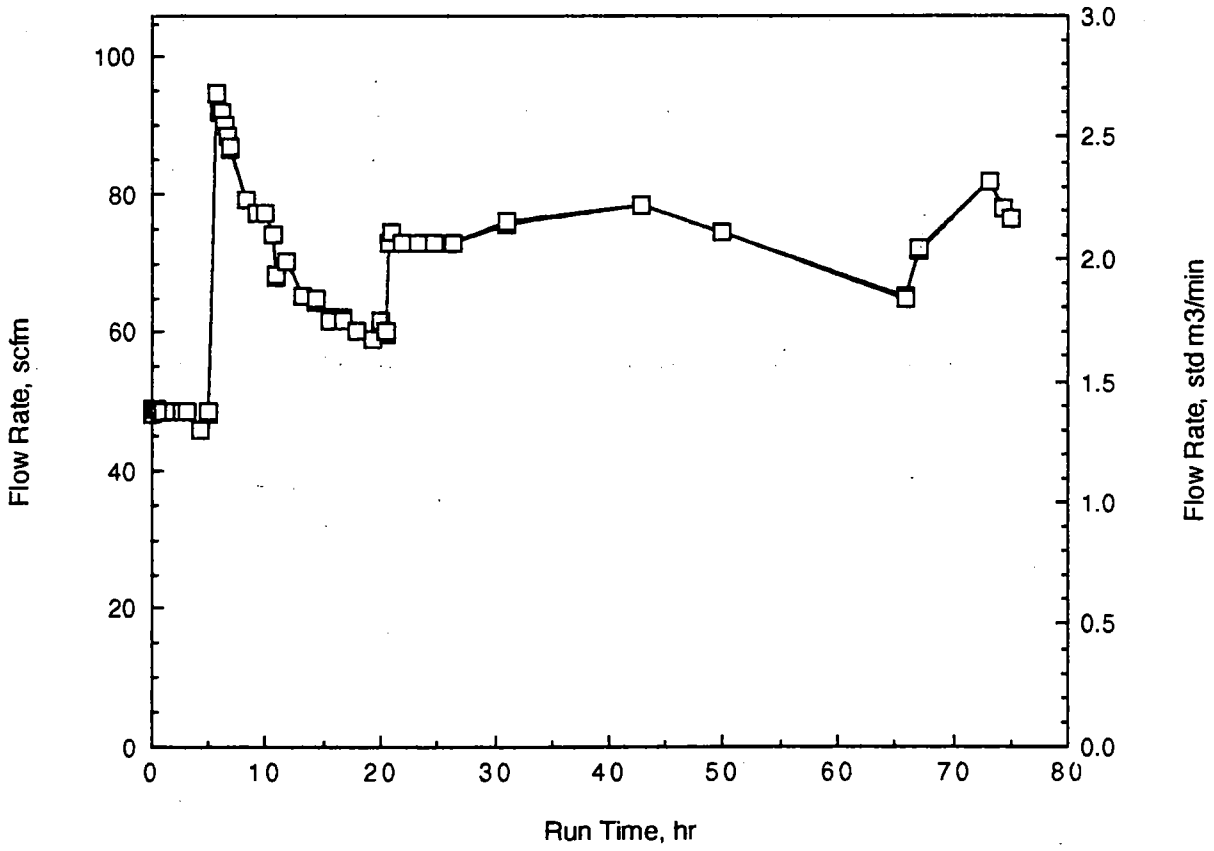


Figure 4-1. 75-Hour Test: Extracted Gas Flow Rate versus Run Time

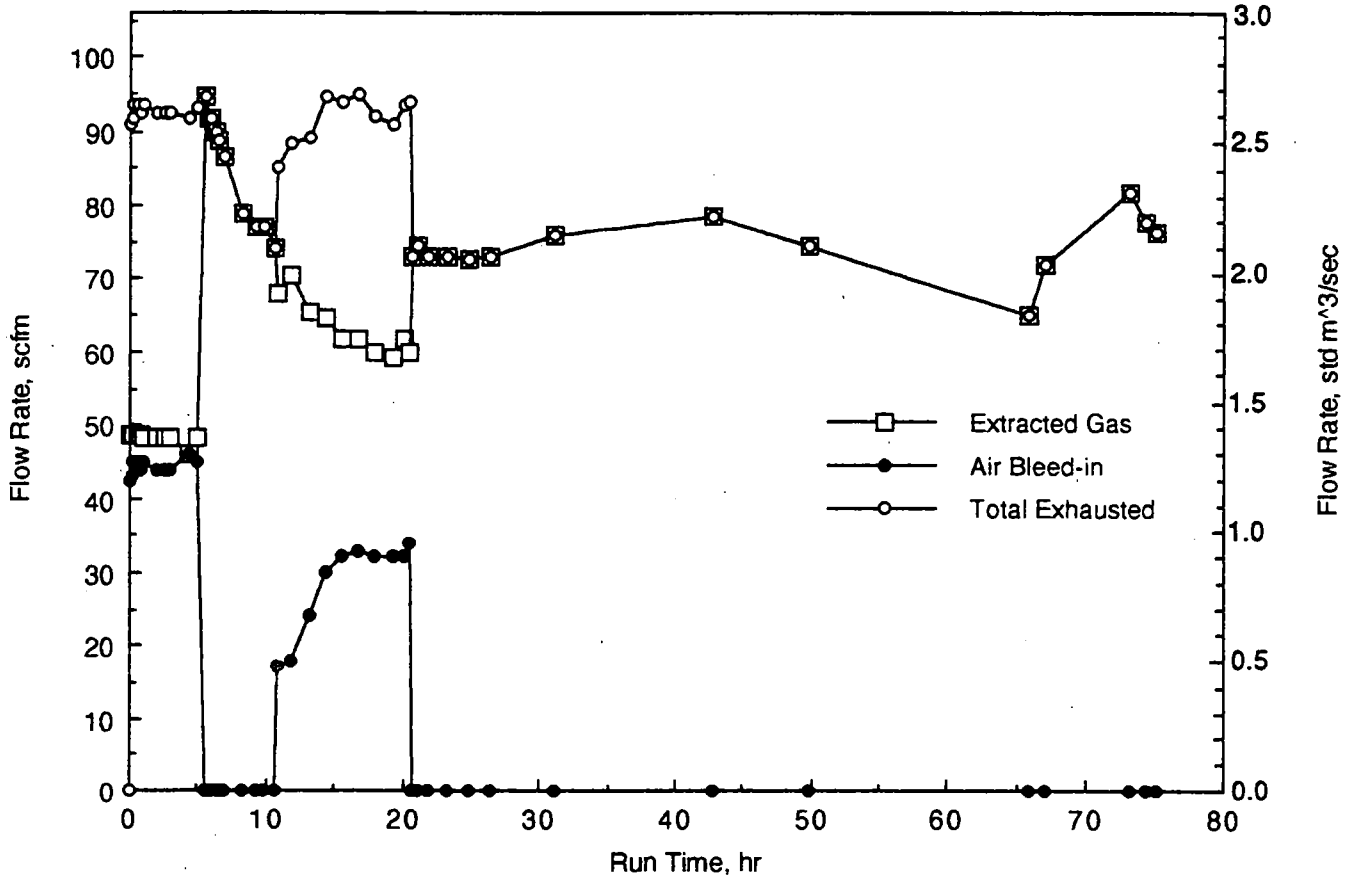


Figure 4-2. 75-Hour Test: Gas Flow Rates versus Run Time

The cumulative volume of gas removed from the landfill during the test is presented in Figure 4-3. Figure 4-4 shows the cumulative volume of gas that went through the blower and carbon unit. The volumes were calculated by multiplying flow rate by elapsed time between specific sampling times during the test and adding the volume from each time step to compute the cumulative volume. The actual numbers used for the calculation and the calculated values are presented in Appendix G. For the 75-hour test, the total volume removed from the landfill was approximately 323,000 std ft^3 (or 9,140 std m^3). The volume of ambient bleed-in air that was introduced during the first 20 hours of the test was approximately 31,500 std ft^3 (or about 900 std m^3). These two volumes were combined to produce a total volume of gas through the blower and carbon unit of approximately 350,000 std ft^3 (or 10,000 std m^3). Thus the volume of bleed-in air was only about eight percent of the total volume through the blower. The extracted gas from the landfill accounted for about 92 percent of the total gas volume through the blower and carbon unit.

4.1.1.2 Vacuum and Pressure Data. Vacuum and pressure data were collected during the 75-hour ISVS test at the mobile ISVS unit and from beneath the landfill cap at the extraction well (EX-1); passive vent 2 (PV-2); and monitoring probes EP-11 and EP-12. The data collected at the mobile ISVS unit are presented in Appendix G. The majority of the vacuum and pressure data collected at the mobile ISVS unit were related to evaluation of the mobile unit operation and not the performance of vapor stripping under the cap. The vacuum data collected from beneath the landfill cap reflected the response of the landfill to the operating conditions produced by the mobile ISVS unit. The vacuum data in the landfill during the test are presented first followed by the various vacuum and pressure data measured or calculated for the mobile unit operations.

Figure 4-5 provides comparison of the vacua at the various monitoring locations beneath the cap with the vacuum at the process trailer. Figure 4-6 presents the vacua measured beneath the landfill cap during the 75-hour test using an expanded scale to highlight the similar behavior of the vacua at locations remote from the extraction well. The captions at the tops of the figures list the extracted gas flow rate events during the test. The vertical lines mark the end of the flow condition described by the text to the right of each line. The vacuum at the extraction well increased from 0 to 20 in.W.C. during the first flow rate period (extracted gas flow rate of about 50 scfm). When the extracted gas flow rate was increased to 95 scfm,

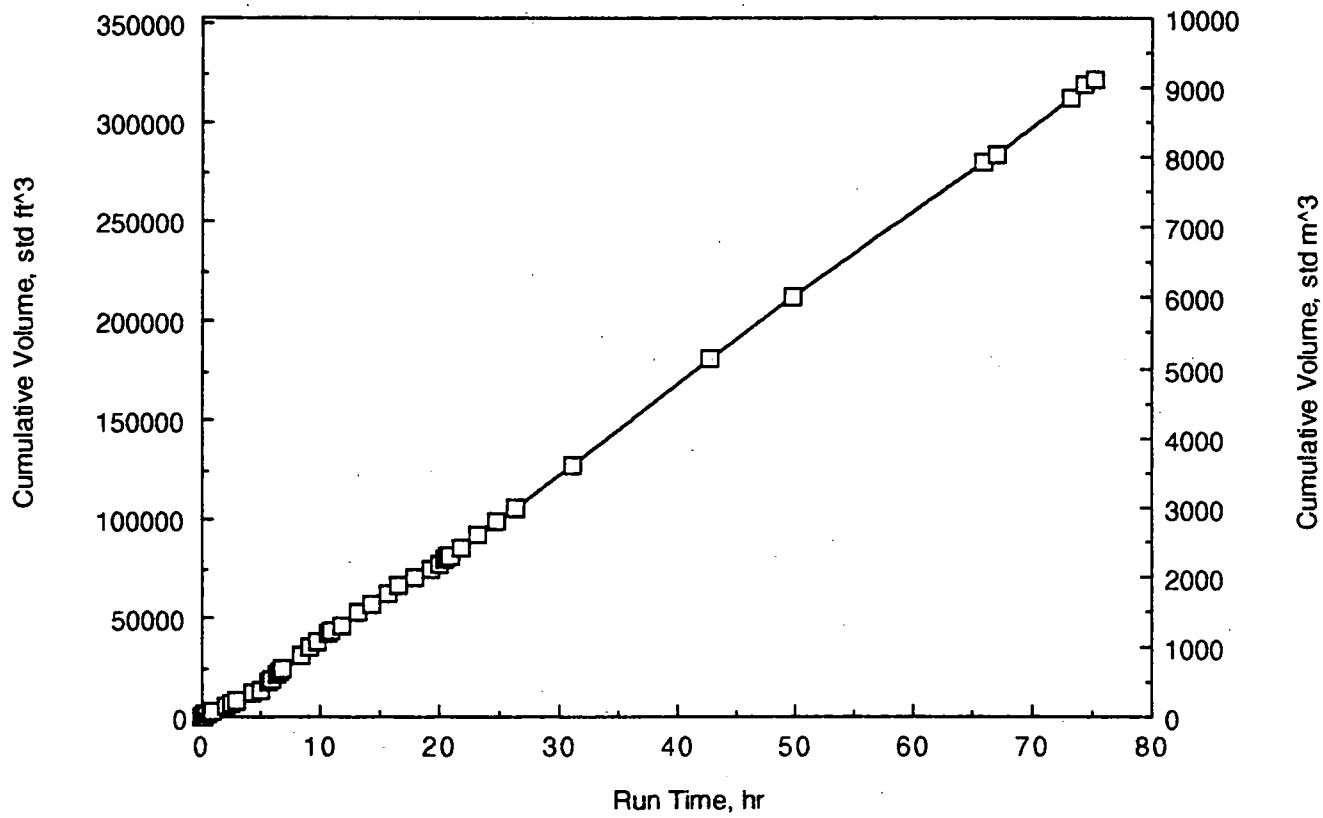


Figure 4-3. 75-Hour Test: Cumulative Volume of Extracted Gas Removed from the Landfill versus Run Time

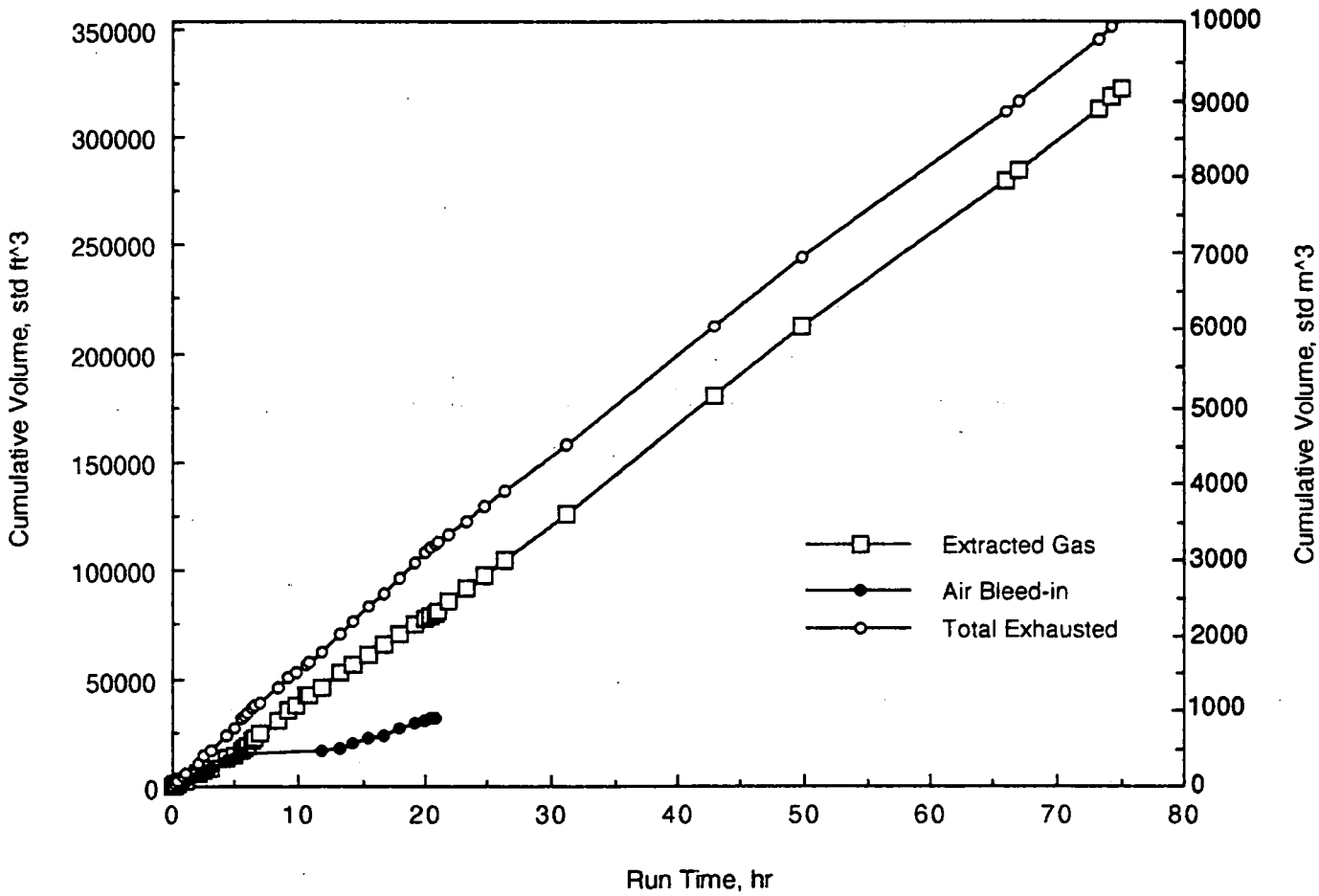


Figure 4-4. 75-Hour Test: Cumulative Volume of Gas Through Blower and Carbon Unit versus Run Time

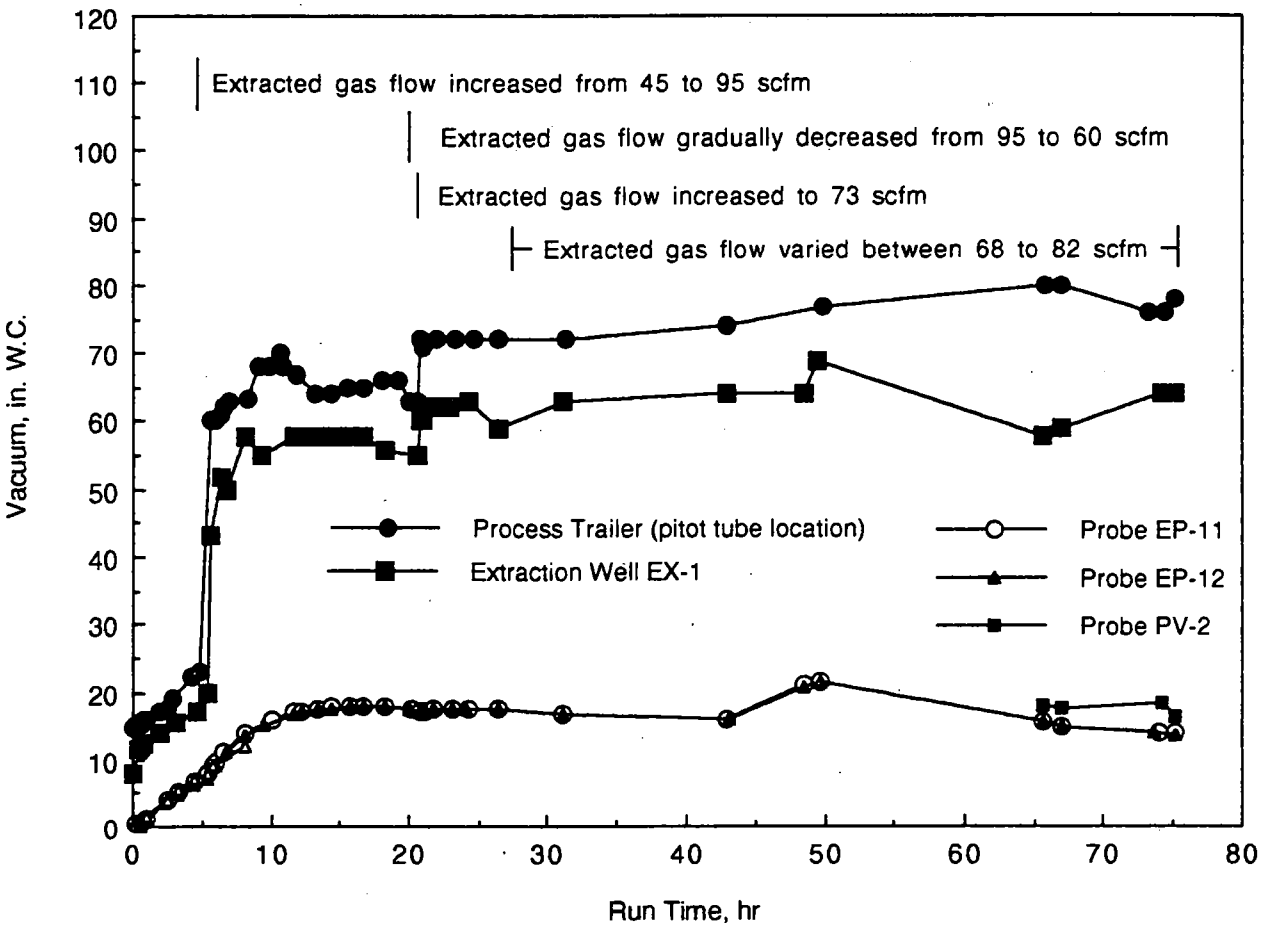


Figure 4-5. 75-Hour Test: Vacua in Landfill and at Process Trailer versus Run Time

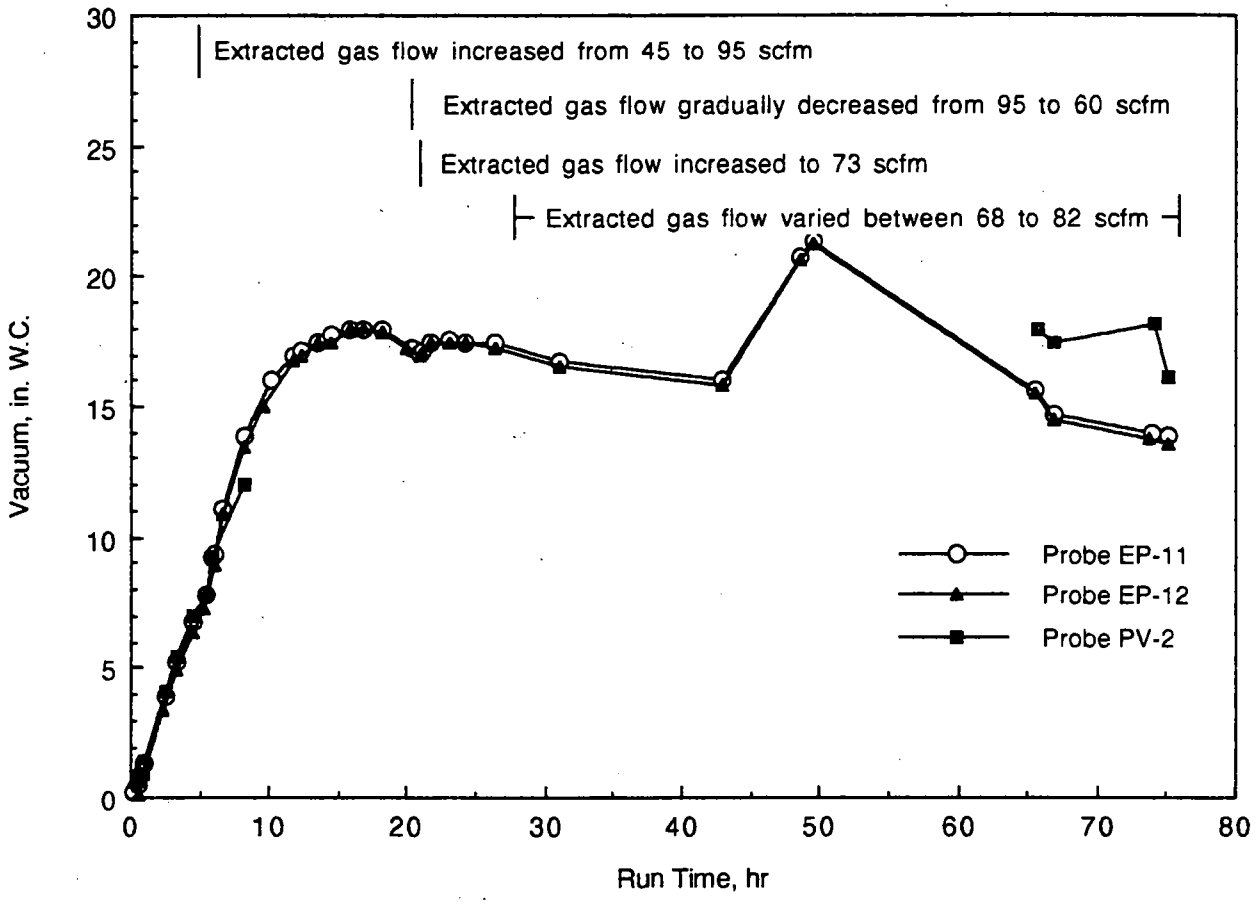


Figure 4-6. 75-Hour Test: Vacua at Probes in Landfill versus Run Time

the vacuum at EX-1 increased immediately to approximately 43 in.W.C. and then increased to 60 in.W.C. during the next three to four hours. The vacuum at EX-1 was between 55 and 70 in.W.C. throughout the duration of the test. Comparison of the vacuum at EX-1 with the vacuum at the process trailer shows the pressure drop in the extraction pipe between the extraction well and the process trailer. A comparison of the vacuum data for PV-2, EP-11, and EP-12 with that for EX-1 shows how the vacuum was relatively uniform across the landfill. Figure 4-6 shows the vacuum data for PV-2, EP-11, and EP-12 on an expanded scale. One can see even more clearly from this figure the similarity in behavior of the vacua at each monitoring point. There are two curves for the vacua for PV-2 (one from 0 to 8 hours and a second between 65 and 75 hours) because the vacuum exceeded the limit of the manometer at approximately eight hours into the test; this problem was corrected by installing a vacuum gauge at PV-2 at approximately 65 hours run time so that final vacuum data could be recorded. Figures 4-7 and 4-8 (expanded scale without extraction well) show the vacua measured after the 75-hour test was complete and reflect the relaxation of the vacua under the landfill cap.

The various vacua and pressures measured or calculated for the mobile ISVS unit are presented in graphical form in Figures 4-9 and 4-10. The vacuum at the pitot tube was relatively low (15 to 25 in.W.C) compared to the blower inlet vacuum (60 to 70 in.W.C.) during the first five hours of operation (see Figure 4-9). This was because of the significant ambient air bleed-in that was used during this time period (refer to Figure 4-2). Air bleed-in was used to a lesser extent between 10 and 20 hours run time and was discontinued completely at about 20 hours. Vacuum data for both the pitot tube location and the blower inlet were approximately the same for the duration of the test ranging between about 70 and 85 in.W.C. The differential pressure across the carbon unit (Figure 4-10) was quite low for the duration of the 75-hour test, never exceeding 2.1 in.W.C. differential. This is well below the pressure drop of 30 in W.C. at the design flow rate of 1,000 cfm. The carbon unit differential pressure showed no buildup during the test which would have been an indication of the collection of water condensate or of general loading. The differential pressure fluctuations were directly related to the total exhaust flow rate (compare Figure 4-10 with Figure 4-2).

4.1.1.3 Temperature Data. Temperature data were collected from beneath the landfill cap and at the process trailer during the 75-hour test. The temperature data

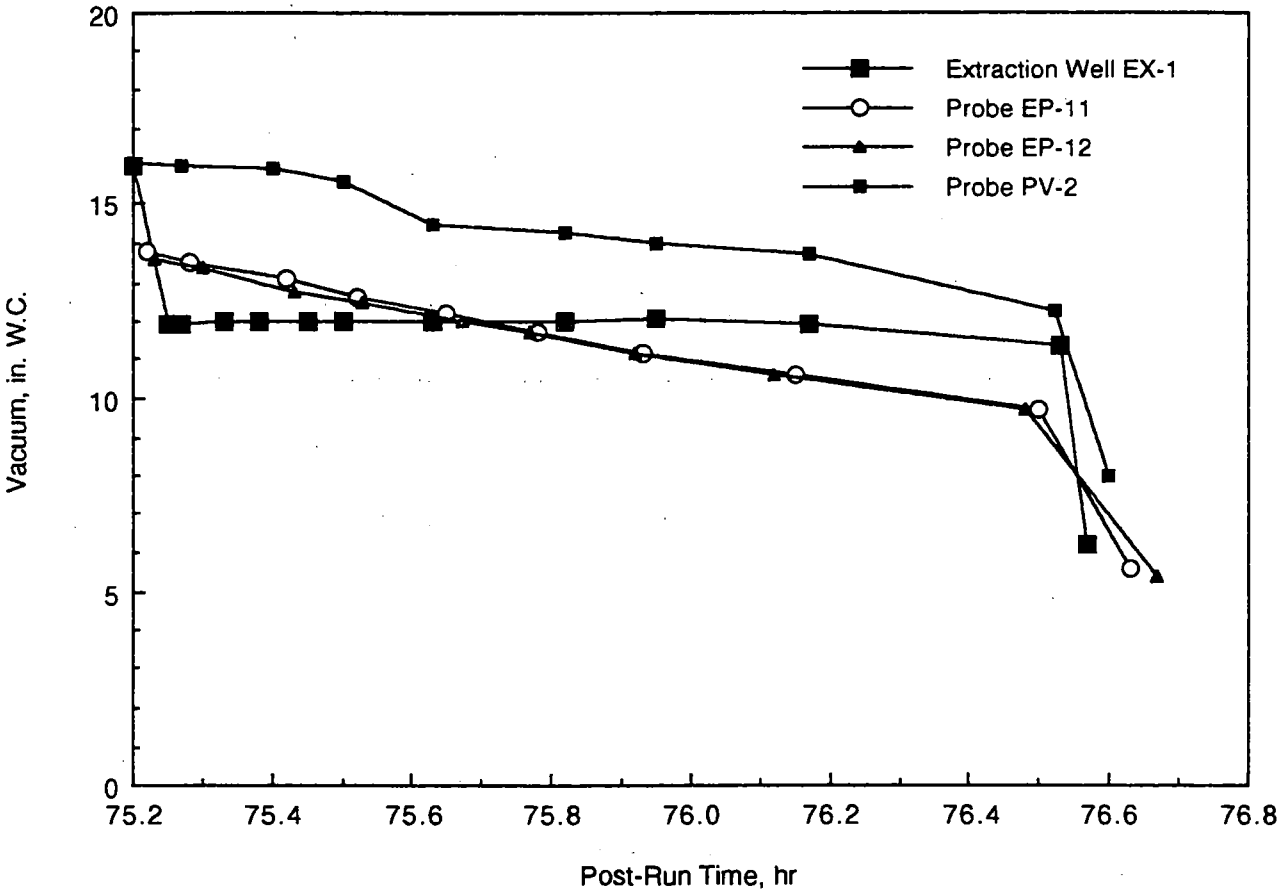


Figure 4-7. 75-Hour Test: Vacua in Landfill after Test Completion versus Time

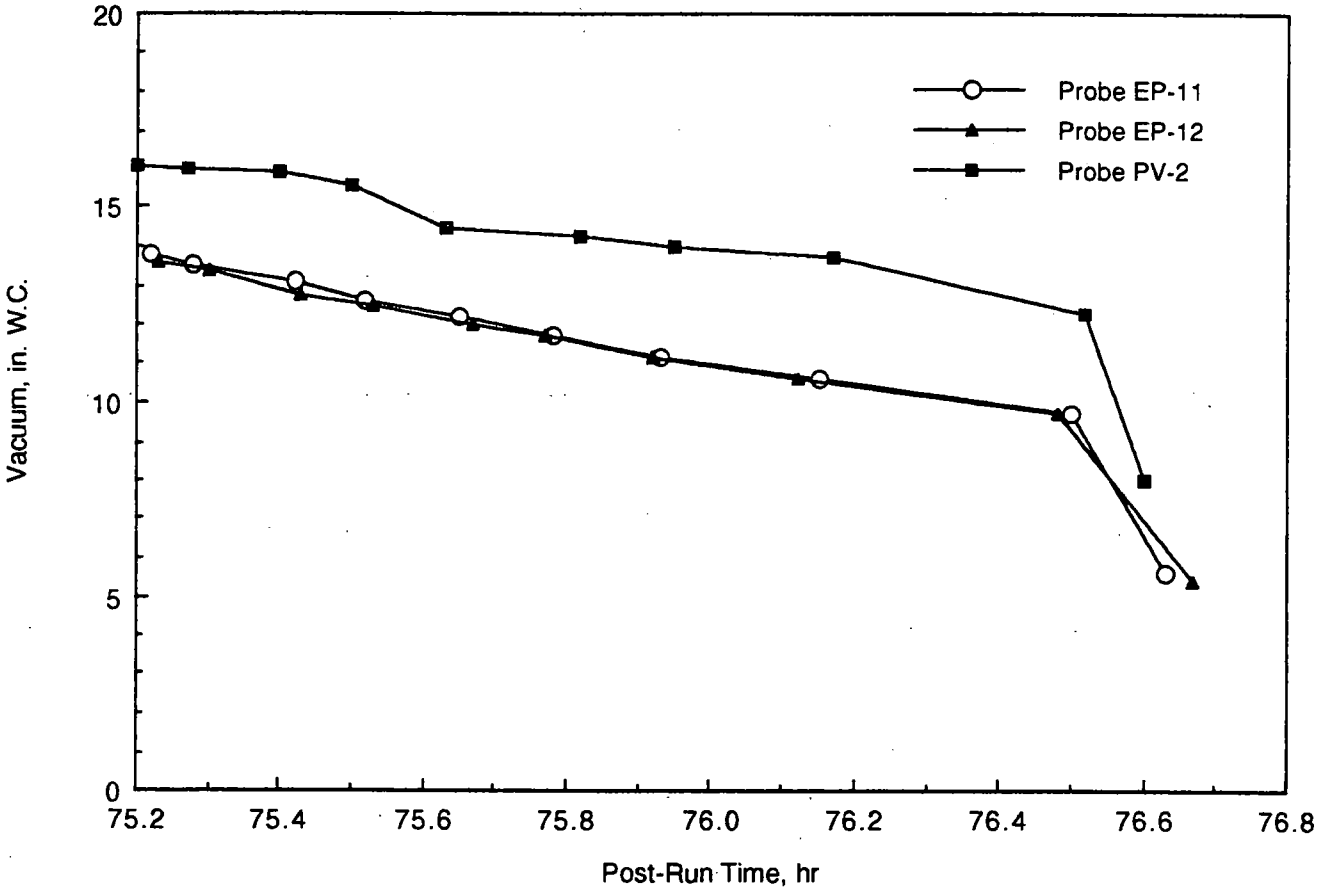


Figure 4-8. 75-Hour Test: Vacua at Probes in Landfill after Test Completion versus Time

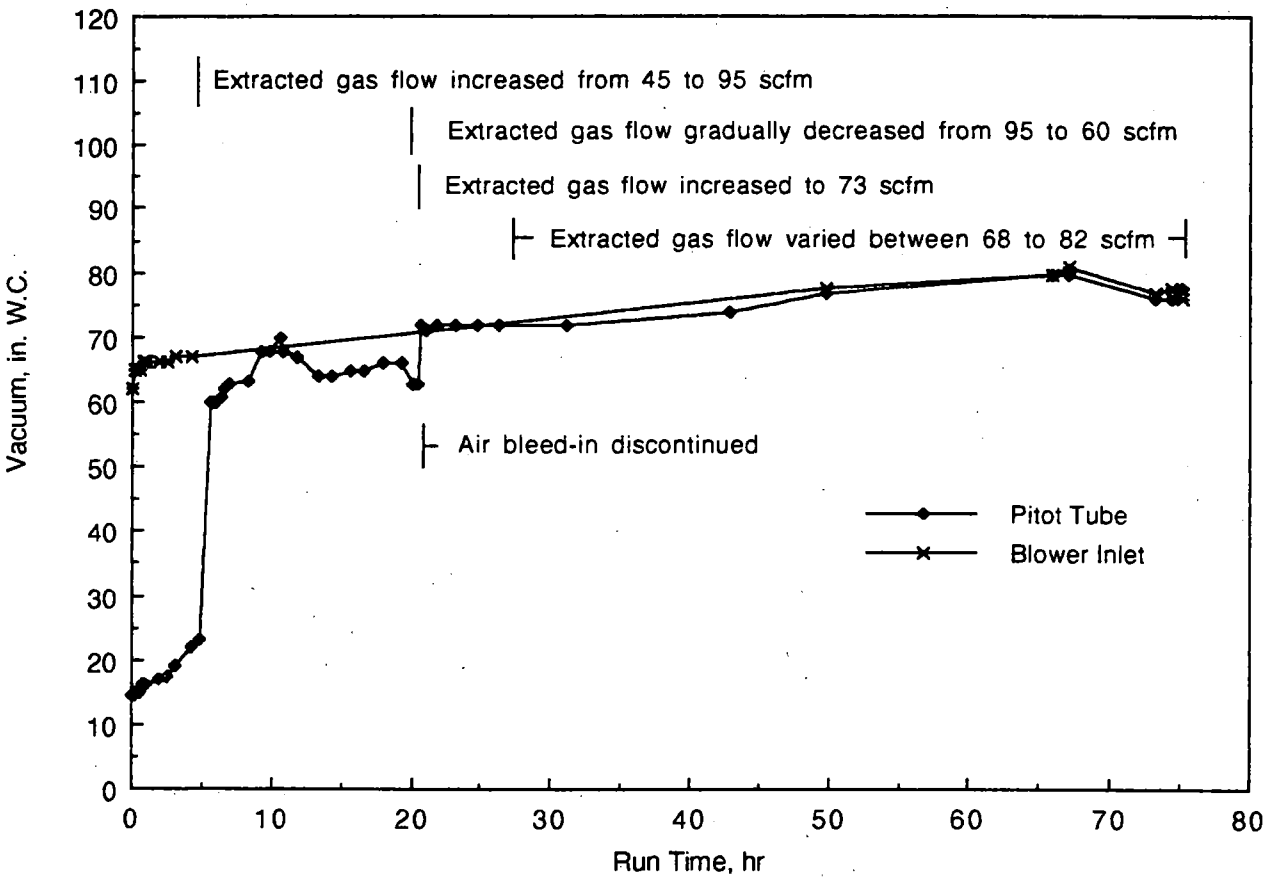


Figure 4-9. 75-Hour Test: Process Vacua at Pitot Tube and Blower Inlet versus Run Time

Note: Changes in extracted gas flow, except for minor variations, were planned either to adjust for air bleed-in needed for system design parameters or to provide data on vacuum/flow relationship.

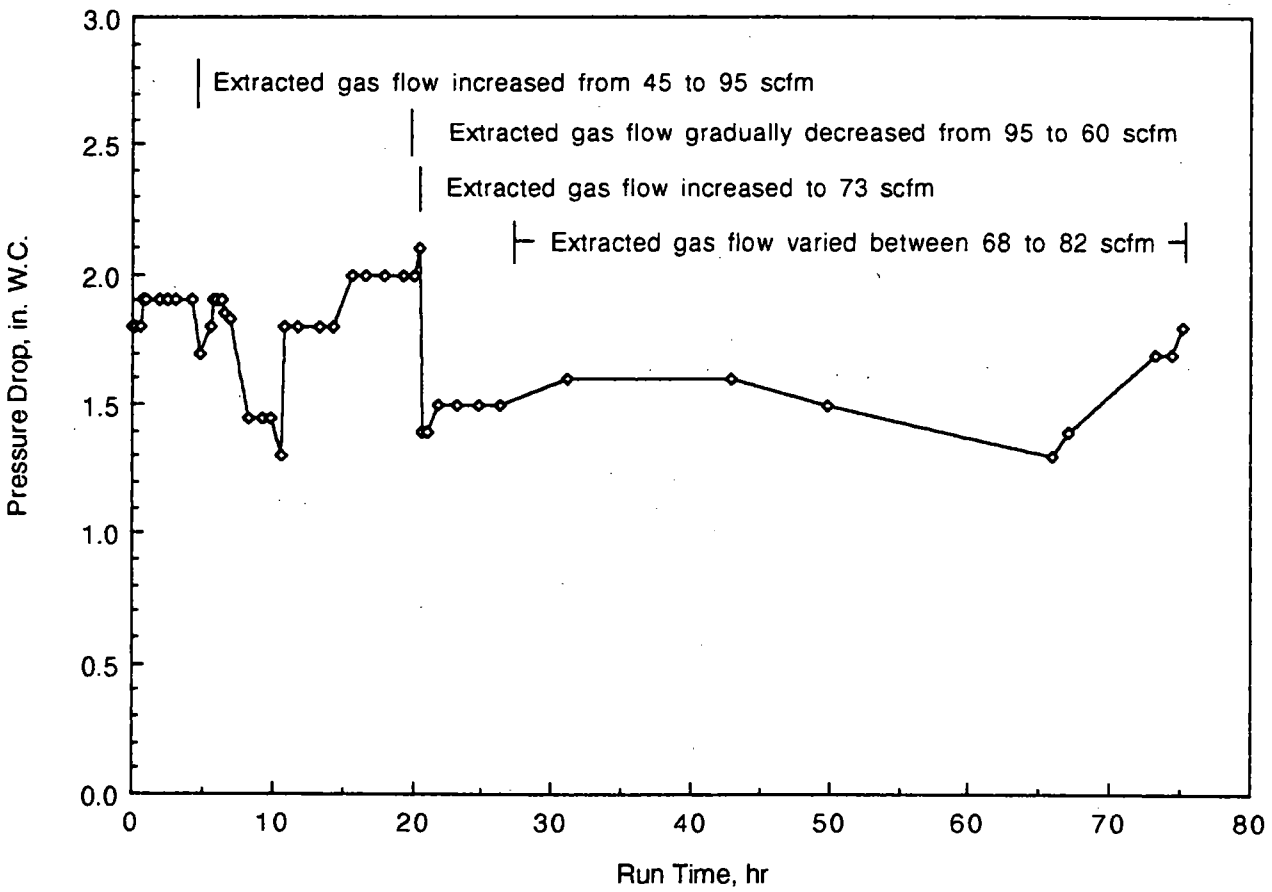


Figure 4-10. 75 Hour Test: Carbon Unit Differential Pressure versus Run Time

from beneath the landfill cap are presented in tabular form in Appendix H and in graphical form in Figure 4-11. In general, the changes in temperature at PV-2, EP-11, and EP-12 followed those at EX-1. The temperatures ranged between about 3 and 11°C (37 and 51.8°F) for the extraction well gas. The temperature data measured beneath the landfill cap should be considered approximately correct because, during the course of the test, some difficulty was encountered with the hand-held temperature read-out unit due to the inclement weather conditions. However, the temperature data given for the process trailer are considered more accurate. The temperature data do show that no thermal buildup occurred within the landfill as the initial anaerobic conditions became more aerobic when air was drawn in from the outside. There was a potential concern that using ISVS at the Lord-Shope landfill site could cause a landfill fire. Therefore, the temperature of the extracted gas was monitored as was the opacity of the gas stream. An increase in either parameter could reflect an incipient fire. Specifically, an increase in opacity during operations could be attributable to the presence of smoke. Per the Work Plan emergency measures were in place including automatic system shut down and an on-call inert gas supply. Introduction of inert gas into the landfill would be used to stop the fire and inhibit its spread. Neither measurement indicated a problem during the duration of the testing. The temperature data was also used to calculate the molar volume of the gas used to convert to the SCFM value employed in various calculations. The molar volume is also used in mathematical models. The temperatures measured at various locations in the process trailer are given in Appendix G and in Figures 4-12 and 4-13. These temperatures are compared to those at the extraction well and outside the process trailer, (i.e., ambient).

Temperature data at the extraction well, demister inlet, and pitot tube tended to the follow the diurnal ambient temperature fluctuation (ambient temperature readings were only taken during the first six hours of operation because the thermocouple failed.) Ambient, blower discharge, blower differential, and carbon exhaust temperatures are shown in Figure 4-13. The blower discharge temperature was significantly higher than the inlet temperature (differential ranged from about 12 to 27°C or 53.6 to 80.6°F) due to the adiabatic heat of compression induced by the blower. This reduced the gas steam humidity prior to treatment by the activated carbon. The temperature also increased somewhat across the carbon bed (compare blower discharge and carbon exhaust temperature in Figure 4-13) due to the heat of

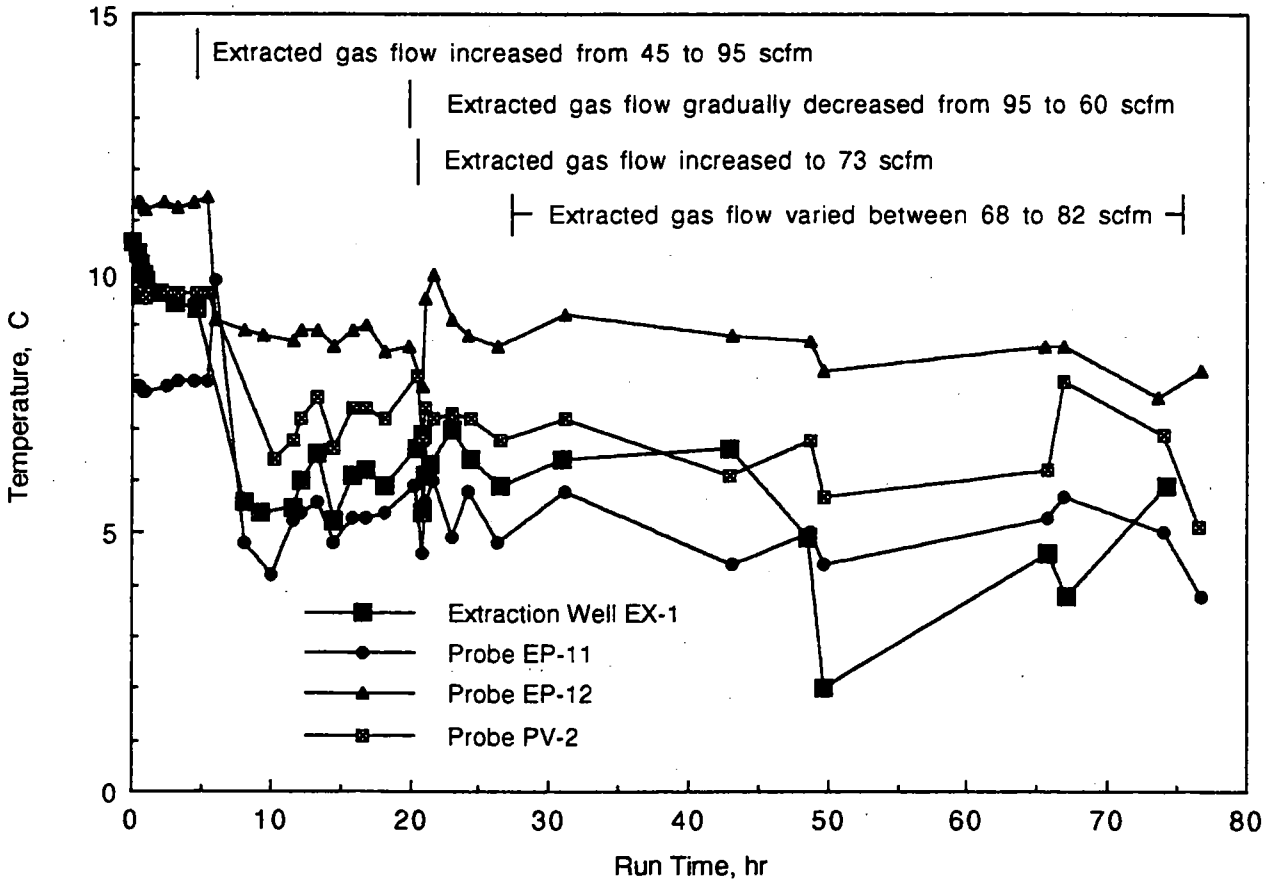


Figure 4-11. 75-Hour Test: Temperatures in Landfill versus Run Time

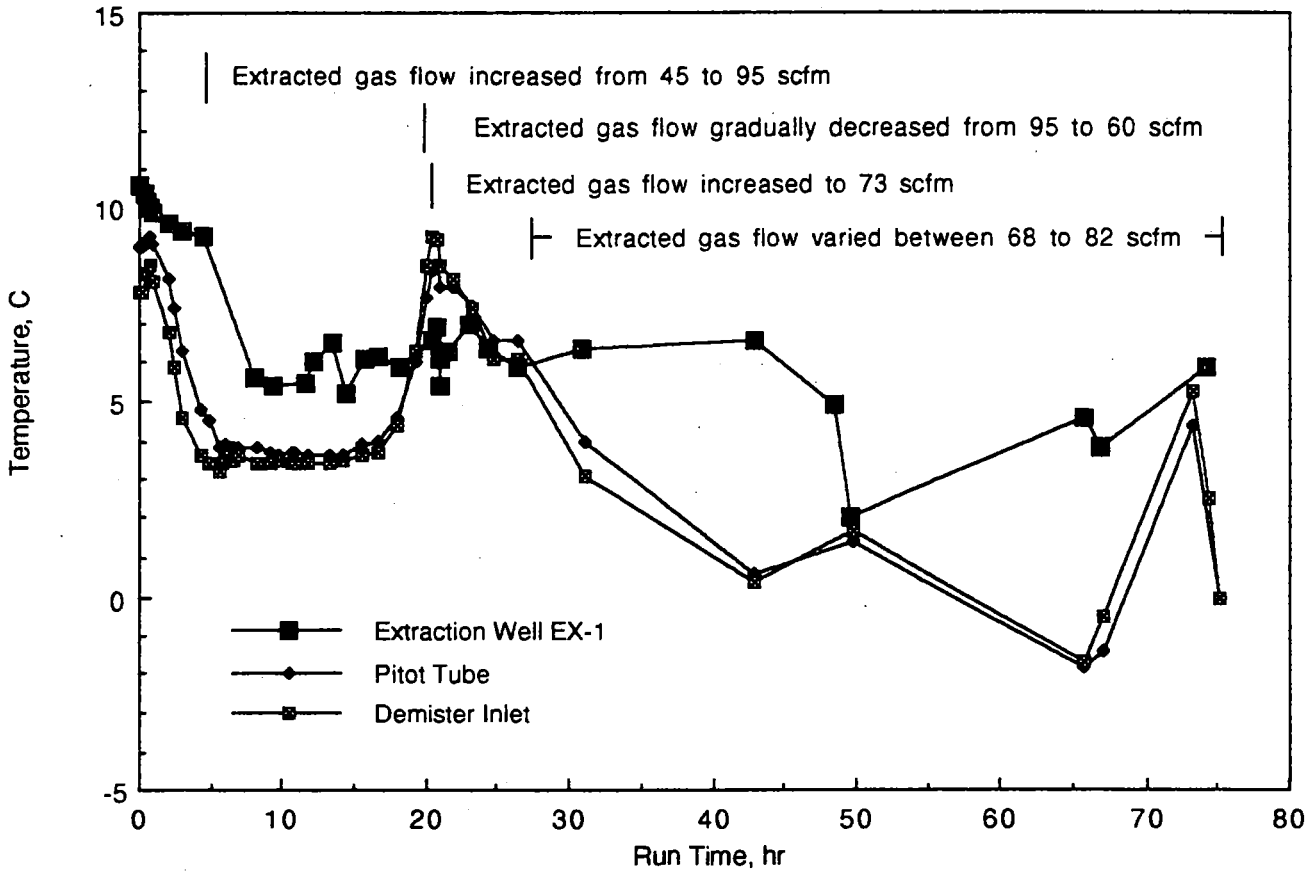


Figure 4-12. 75-Hour Test: Temperatures at Extraction Well EX-1 and Process Trailer versus Run Time

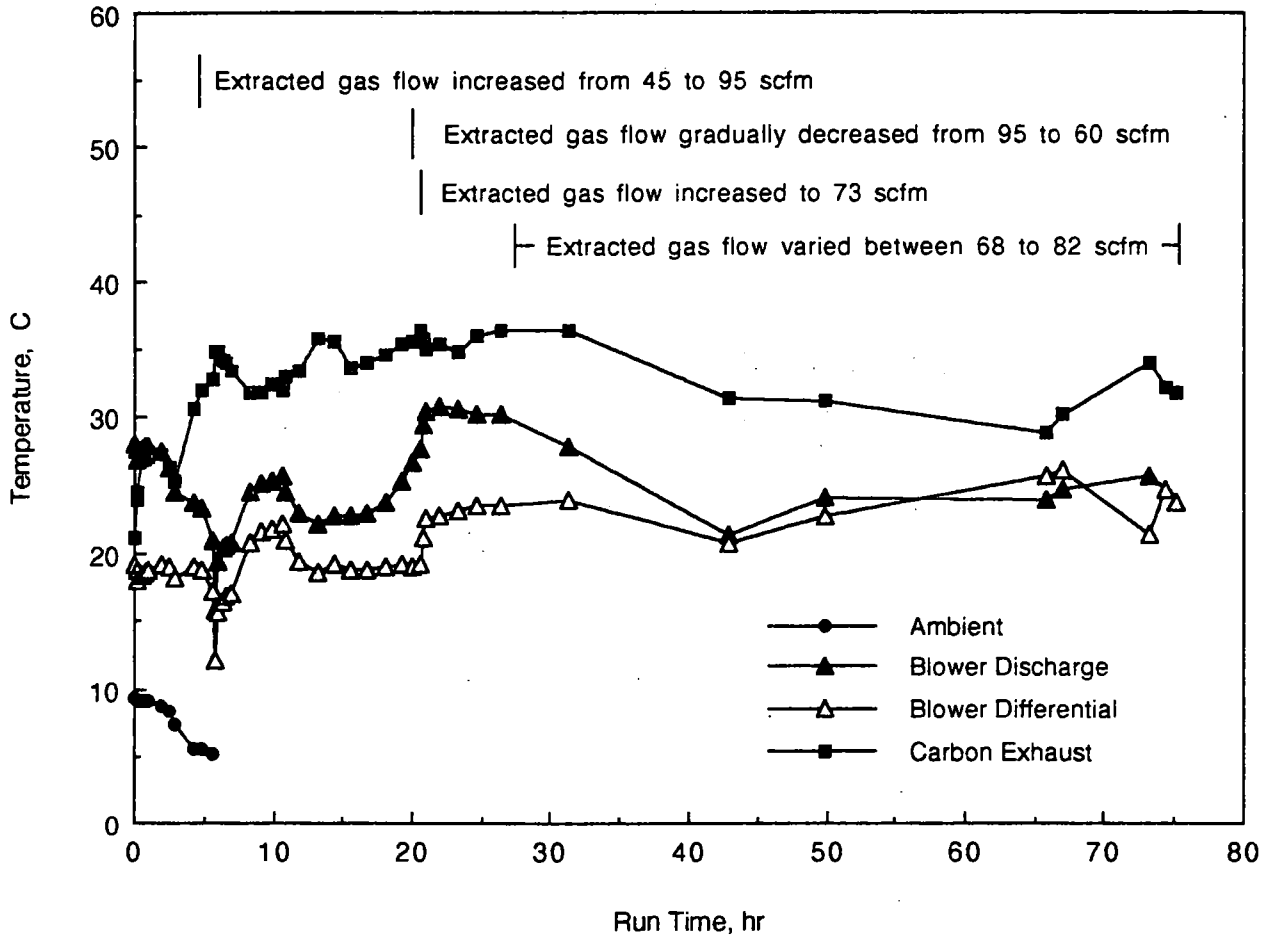


Figure 4-13. 75-Hour Test: Temperatures at Process Trailer versus Run Time

adsorption of the vapor phase organic contaminants as they were removed by the carbon.

4.1.2 Soil-Gas Data

The soil-gas data collected during the 75-hour ISVS test consist of field monitoring data measured with various hand-held gas monitoring instruments and of chemical specific data from laboratory analysis of gas samples taken during the test. Soil-gas monitoring and sampling data were taken at the extraction well (EX-1) and monitoring probes EP-11 and EP-12. The schedule and locations for soil gas data collection are given in Appendix C. Qualitative and semi-quantitative chemical specific data were reported in the interim report (see Appendix B) for gas samples taken during the Part 1 Testing. All specific discussion of QA/QC samples is included in Section 4.6.

4.1.2.1 Field Monitoring Data. Field monitoring data were collected with hand-held instruments following the schedule given in Appendix C. The actual monitoring times and locations are given in Appendix H along with the data collected. As discussed previously, the diaphragm gas sampling pump was used to draw the gas to the monitoring instruments during the test. The monitoring instruments used were the organic vapor analyzer, OVA, (outfitted with a flame ionization detector), explosimeter, and HNu (outfitted with a photoionization detector with an 11.7 eV lamp). See Section 2.3 for more information on these instruments. Due to the high methane concentrations in the soil gas within the landfill, the OVA and explosimeter readings were beyond the scale of the instrument for the duration of the test. The data from the HNu are presented in Figure 4-14. The concentrations measured at EP-11 were similar to those at EX-1; the concentrations measured at EP-12 were lower than those at EX-1 but follow the same trend.

When the HNu monitoring data are compared to the chemical specific data in the next section, it becomes apparent that the HNu data followed an opposite trend to those shown for methane and total VOCs. The graphs of percent methane and total VOCs show that concentrations generally decreased during the course of the test. After consulting with HNu technical service personnel, it has been determined that methane is a strong quencher of the photoionization process in the HNu instrument.

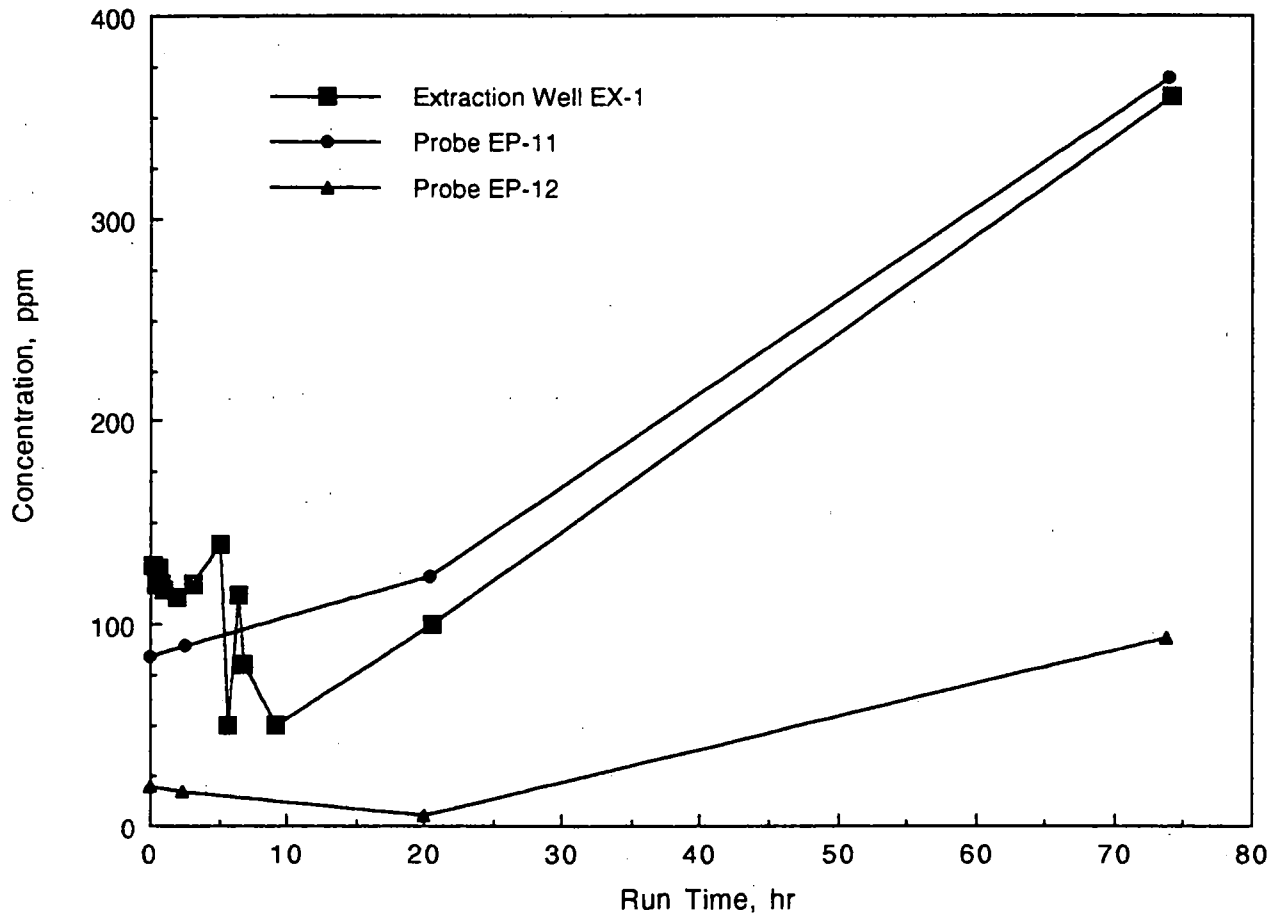


Figure 4-14. 75-Hour Test: HNu Monitoring Data Measured on Landfill versus Run Time

Therefore, as the methane concentration decreased in the gas, less quenching or repression of the detector response occurred, allowing a better measurement of the concentration of the other VOCs in the gas. The HNu also gives low relative response readings to some of the compounds of interest, e.g., 10 ppm toluene reads 8.2 ppm, 10 ppm tetrahydrofuran reads 6.5 ppm, and 10 ppm 2-propanol reads 3.7 ppm. These two factors, i.e., quenching by the methane and low relative response to certain chemicals, contribute to the overall read-out from the HNu which results in the graph which shows an upward trend, opposite to that observed from the chemical specific data. All evaluations and conclusions should therefore be made using the chemical specific data.

4.1.2.2 Chemical Specific Data. Chemical specific data have been produced from analyses of gas samples collected in Tedlar® bags during the 75-hour test at the extraction well (EX-1), monitoring probes EP-11 and EP-12, and at the carbon exhaust. All data pertaining to the activated carbon usage and performance are given in Section 4.5.1. Tedlar® bag samples were analyzed for methane (analysis according to method described in Appendix J) or the list of chemicals in Table 2-4 (analysis according to modified Method TO-14, see Section 2.4.2). Summary data sheets have been produced for each sample analyzed by modified Method TO-14. The raw data for all samples as supplied by the analytical laboratories are archived in-house (ECKENFELDER INC.) and are available upon request. The summary data sheets are provided in Appendix I and are organized according to sampling location. Each data sheet has the sample number, analysis date, and analytical laboratory listed at the top of the page. The body of the summary data sheets lists the chemicals on the analyte list, the concentrations reported, comments as appropriate, dilution factors, and total VOC concentrations. The last line in the table gives the sampling time.

The analysis of gas samples for methane was added to the Part 2 Testing sampling schedule as a result of the findings from the Part 1 Testing. The results of the methane-specific analyses of all samples taken during Part 2 Testing are included as Appendix J. Table 4-3 shows the percent methane (%) content reported for samples collected during the 75-hour ISVS test. The actual data and sample numbers can be acquired by cross-referencing the data given in Appendices H and J. Figure 4-15 shows the data from Table 4-3 in graphical form. The percent methane content generally decreased during the test at all sampling locations except EP-12. The

TABLE 4-3

PERCENT METHANE IN GAS SAMPLING DURING 75-HOUR ISVS TEST

Sample Location	Sampling Time[a] (hr)	Methane (%) (v/v)
Extraction Well	0.17	47
	1.00	46
	20.50	31
	74.17	7[b]
	74.17	8[b]
EP-11	0.00	43
	20.25	37
	73.92	14
EP-12	0.00	29
	9.92	38
	19.97	37
	73.67	30[c]
	73.67	27[c]
Carbon Unit Exhaust	1.70	21
	10.78	36
	19.80	18
	73.50	11

[a]Sampling time is listed as run time relative to start of 75-hour ISVS test.
[b]Duplicate samples.
[c]Duplicate samples.

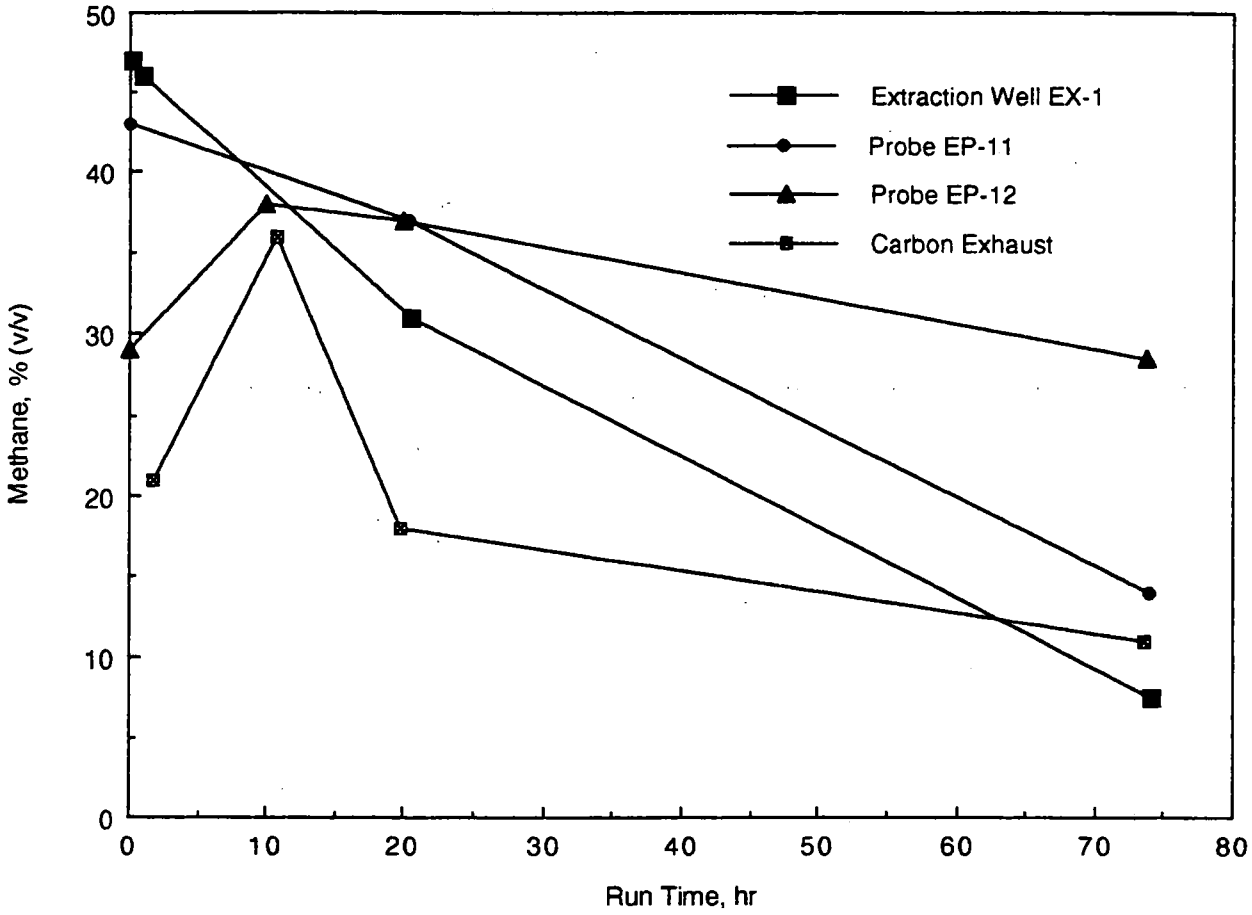


Figure 4-15. 75-Hour Test: Percent Methane in Samples Taken from Landfill and at Carbon Exhaust versus Run Time

methane content in EP-12 samples stayed more-or-less constant throughout the test. This behavior could reflect the relatively small volume of air drawn through the relatively large volume under the cap that is associated with this well. This result could also reflect a large reservoir of methane in proximity to the well which was not significantly impacted during the 75 hour test. Either or both is consistent with the concept of the heterogeneous nature of the landfill as well as with the later conclusions drawn regarding the pneumatic permeability of the landfill (see Section 5).

The methane content in the gas at the extraction well decreased by approximately a factor of six during the course of the test; this was the most dramatic decrease observed. The methane content in the extracted gas was used in the calculation of the flow rates reported in section 4.1.1.1, since the methane concentration affects the specific gravity of the gas (see Appendix G).

Table 4-4 presents a qualitative summary of the compounds detected above the limit of quantitation (LOQ) in the Tedlar® bag samples taken during the Part 2 Testing. The LOQ is the lowest concentration that can be reported with accuracy and includes factors for the method detection limit, matrix effects, and dilution factors. For the concentrations reported by Lord Corporation, the LOQ was 10 ppb (v/v) multiplied by the dilution factor for a given sample. Lord Corporation Analytical Services, Erie, Pennsylvania provided the primary chemical analyses; Ross Analytical Laboratory, Strongsville, Ohio provided external QA/QC. Chloromethane and 1,1,2,2-tetrachloroethane were analyzed for but not detected in any samples by either laboratory. Ross Analytical Laboratory included methylene chloride and 4-methyl-2-pentanol in their list of analyses. Also, Ross Analytical Laboratory reported total xylenes rather than o-xylene and m-xylene (1,2-dimethylbenzene and 1,3-dimethylbenzene, respectively).

Table 4-5 presents a quantitative summary of the compounds above the LOQ in samples taken at the extraction well during the 75-hour test. Because methane analyses were performed on separate samples, the mass of methane is not included as part of the total VOCs. Vinyl chloride and 1,2-dichloroethene (total, both cis and trans isomers) accounted for 89 percent of the total VOCs removed from the extraction well during the 75-hour test. Approximately 1,400 kg (3,100 pounds) methane and 265 kg (580 pounds) total VOCs were removed from the landfill during

TABLE 4-4

QUALITATIVE SUMMARY OF COMPOUNDS DETECTED ABOVE THE LOQ IN GAS SAMPLES COLLECTED DURING PART 2 TESTING

Lord-Shope ISVS Sample Analyses Results (Analysis by Modified Method TO-14)

Compound	Sampling Location			
	Extraction Well	EP11	EP12	Carbon Exhaust
Chloromethane	ND	ND	ND	ND
Vinyl Chloride	X *	X *	X	X
Acetone	X	X	X (Ross only)	ND
2-Propanol(Isopropanol)	X	X	X	ND
1,2-Dichloroethene(Total)	X	X	X	X
1,1-Dichloroethane	X	X	X	ND
2-Butanone	X	X *	X	ND
2-Butanol(sec-Butanol)	X	X	X	ND
Chloroform	X	X	ND	ND
Tetrahydrofuran	X	X	X	ND
Benzene	X	X	X (Ross only)	ND
Trichloroethene	X *	X *	X	X
4-Methyl-2-Pentanone	X *	X *	X	X
Toluene	X *	X *	X	X
Tetrachloroethene	X *	X *	X *	ND
Chlorobenzene	ND	X	ND	ND
1,3-Dimethylbenzene	X *	X *	X	X
Cyclohexanone	X	X	ND	ND
1,2-Dimethylbenzene	X *	X *	X	X
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND
Methylene Chloride	X (Ross)		X (Ross)	
Xylenes (Total)	X (Ross)		X (Ross)	
4-Methyl-2-Pentanol	X (Ross)		X (Ross)	

LOQ = Limit of Quantitation
ND = Not detected above the LOQ in any sample
X = Detected above the LOQ in at least one sample
Ross = Detected in sample analyzed by Ross Analytical Laboratory
* Indicates compound identified in sample taken during the preliminary, small scale sampling in November 1991. (See Appendix R.)

TABLE 4-5

SUMMARY OF CHEMICAL-SPECIFIC DATA FOR EXTRACTION WELL GAS SAMPLES TAKEN DURING 75-HOUR ISVS TEST

Compound	Total Mass Removed (g)	Concentration Range[a] ppm (v/v)	
		Low	High
Vinyl chloride	124,000	2,900	7,700
Acetone	5.64	ND[b]	5.4
2-Propanol	6.58	ND	2.3
1,2-Dichloroethene (total)	112,000	1,700	4,300
1,1-Dichloroethane	227	0.3	6.7
2-Butanone	296	4.7	13
2-Butanol	19.3	ND	5.9
Chloroform	36.7	ND	0.95
Tetrahydrofuran	426	ND	77
Benzene	203	0.7	7.4
Trichloroethene	14,900	14	410
4-Methyl-2-pentanone	5,620	20	630
Toluene	3,970	85	240
Tetrachloroethene	736	0.85	17
1,3-Dimethylbenzene	890	ND	42
1,2-Dimethylbenzene	1,260	3.9	41
Total VOCs (excluding Methane)	265,000[c]	4,970[d]	12,500[d]
Methane[e]	1,400,000	7% (v/v)	47% (v/v)

[a]Reported by Lord Corporation Laboratory.
[b]Not detected above limit of quantitation (LOQ).
[c]Vinyl chloride and 1,2-Dichloroethene account for 89 percent of the total.
[d]Represents the low and high concentrations of total VOCs as reported on data sheets in Appendix I-1 and is not a sum of the individual high and low concentrations shown in this table.
[e]Reported by Twin City Testing Corporation.

the 75-hour test. (Lord Corporation notified the appropriate regulatory agencies regarding the vinyl chloride emission, which exceeded the reportable quantify (RQ).) The concentration range reported for each compound is also given in Table 4-5. Figure 4-16 shows the mass of the major organic compounds removed from the extraction well. A similar graph is presented in Figure 4-17 which shows all the compounds detected in the extraction well gas samples except methane. The data presented in Table 4-5 and Figures 4-16 and 4-17[1] were calculated from concentration data reported by the Lord Corporation Laboratory and from process data measured or calculated as given in Appendix G. An example of the calculation of total mass removed and any assumptions made are included in Appendix K.

Figures 4-18, 4-19, and 4-20 show the concentrations of total VOCs, vinyl chloride, and 1,2-dichloroethene (total) for gas samples taken at the extraction well, EP-11, and EP-12, respectively. Only data from the Lord Corporation Laboratory were used for these graphs. All discussion of Ross Analytical Laboratory QA/QC results is presented in Section 4.6. At all sampling locations, vinyl chloride and 1,2-dichloroethene (total) were in highest concentrations relative to the other compounds detected; the concentrations of these two compounds combine to make up most of the concentration shown as total VOCs in each graph. Figure 4-21 shows the concentrations of total VOCs at each sampling point. Additional graphs of chemical specific data for the sampling points are given in the appropriate section of Appendix K. All chemical specific data samples taken at the carbon exhaust are provided in either section 4.5.1 or Appendix S.

4.1.3 Discussion of Results

The results of the 75 hour test provided a large amount of information relevant to the conduct of full scale remediation at the site. Of primary importance is the fact that large amounts of VOCs are able to be removed from under the cap. In the 75 hour test period, a total of 1,665 kg (3,665 pounds) was removed from the extraction well in 9,140 standard m^3 (323,000 standard ft^3). This represents an average concentration of 182 g/standard m^3 (0.011 pound/standard ft^3). Of this mass of VOCs removed, 1,400 kg (3,080 pounds) was methane and 124 kg (273 pounds) was vinyl chloride, The presence of this amount of small, labile

[1]Note the change in the scale on the x-axis.

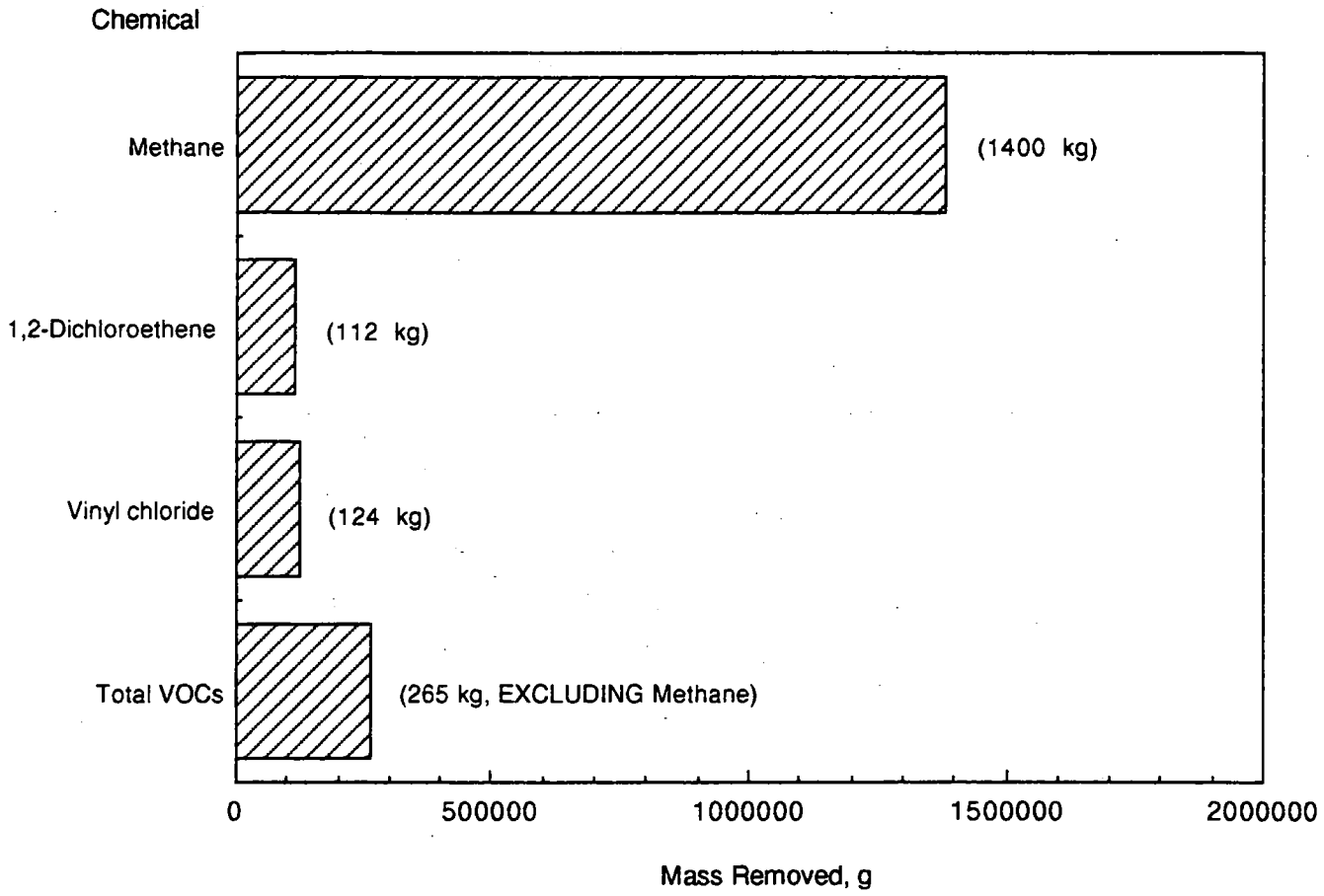


Figure 4-16. 75-Hour Test: Mass of Major Organic Compounds Removed from Extraction Well EX-1

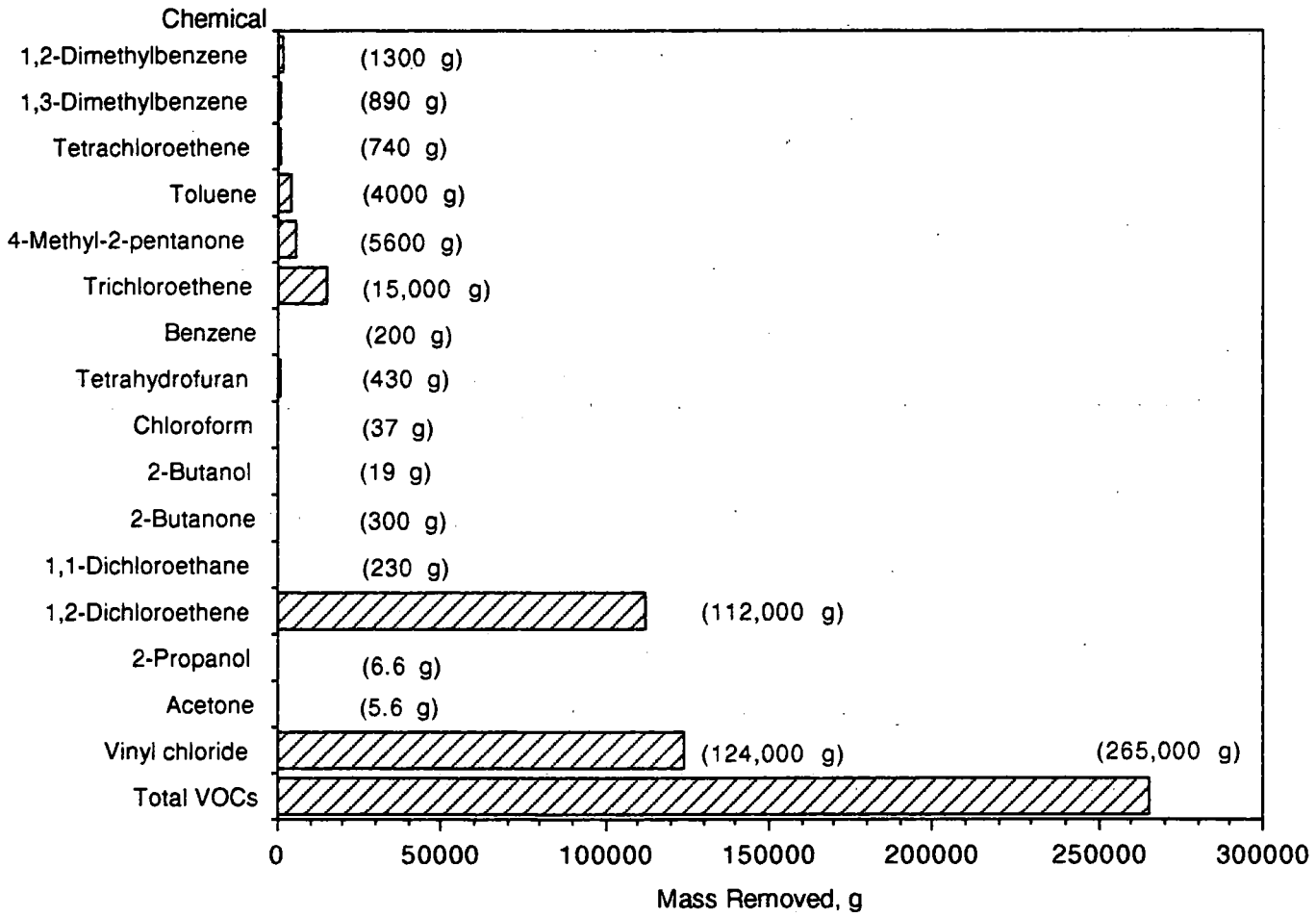


Figure 4-17. 75-Hour Test: Total Mass of VOCs (excluding methane) Removed from Extraction Well EX-1

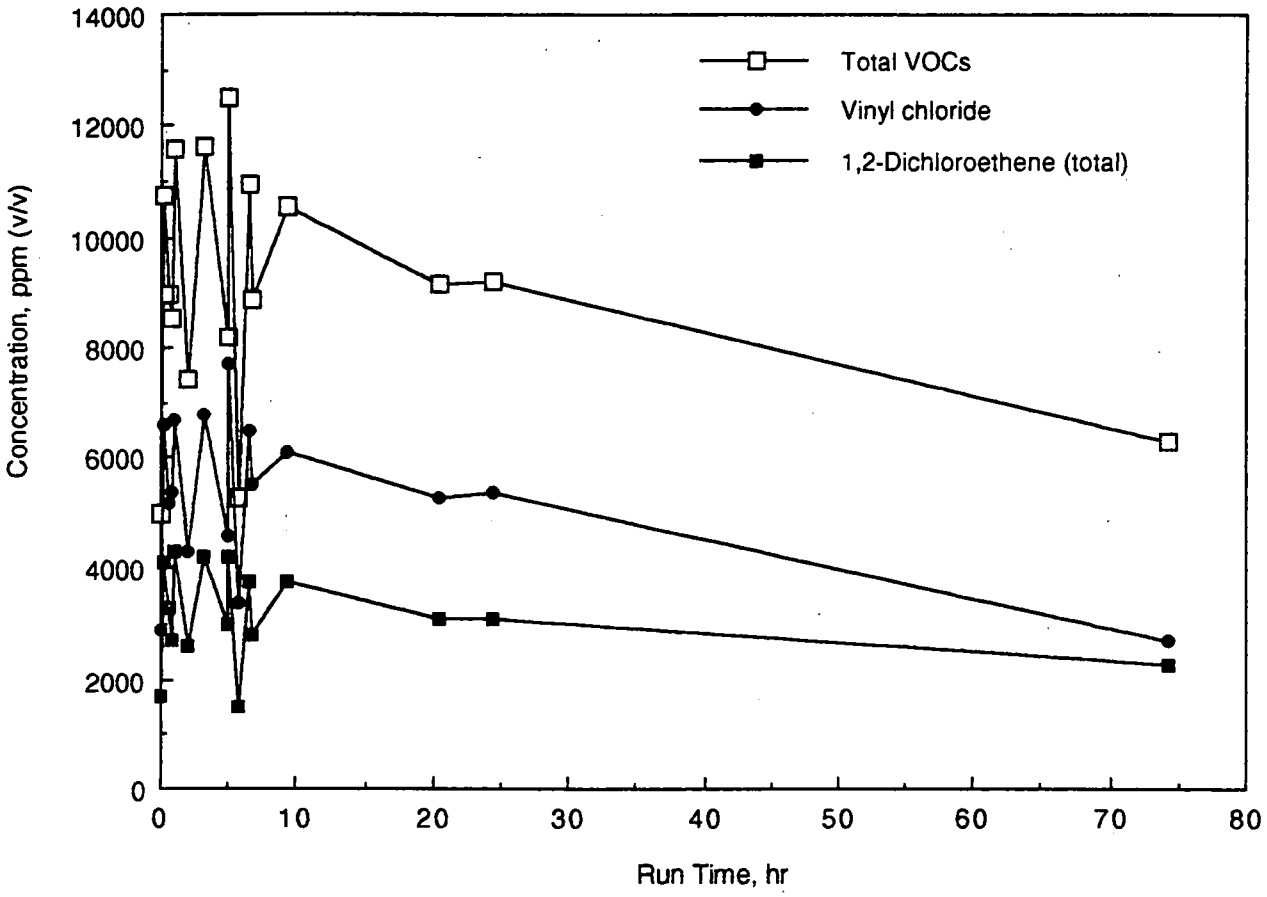


Figure 4-18. 75-Hour Test: Concentrations of Major Compounds and Total VOCs (excluding methane) for Extraction Well EX-1 Gas Samples versus Run Time

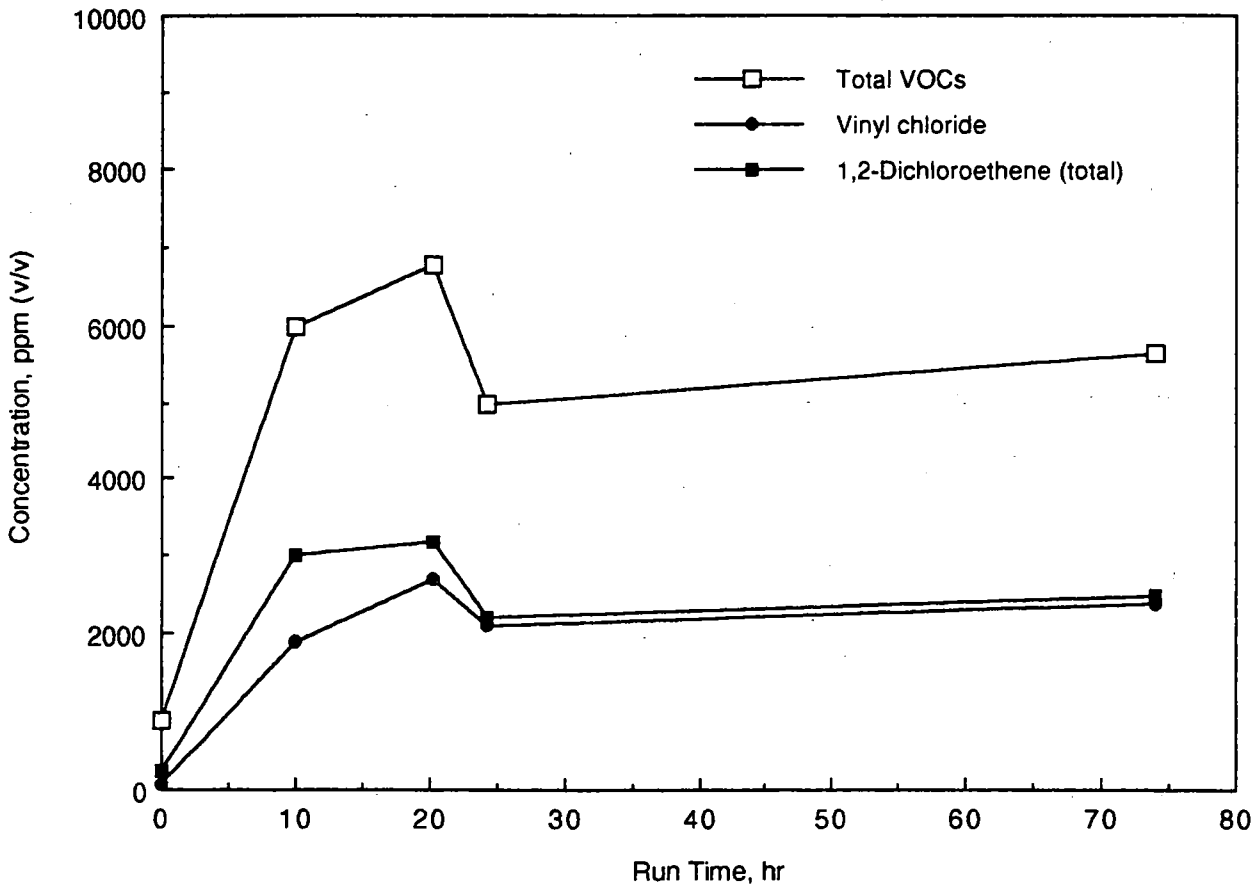


Figure 4-19. 75-Hour Test: Concentrations of Major Compounds and Total VOCs (excluding methane) for Probe EP-11 Gas Samples versus Run Time

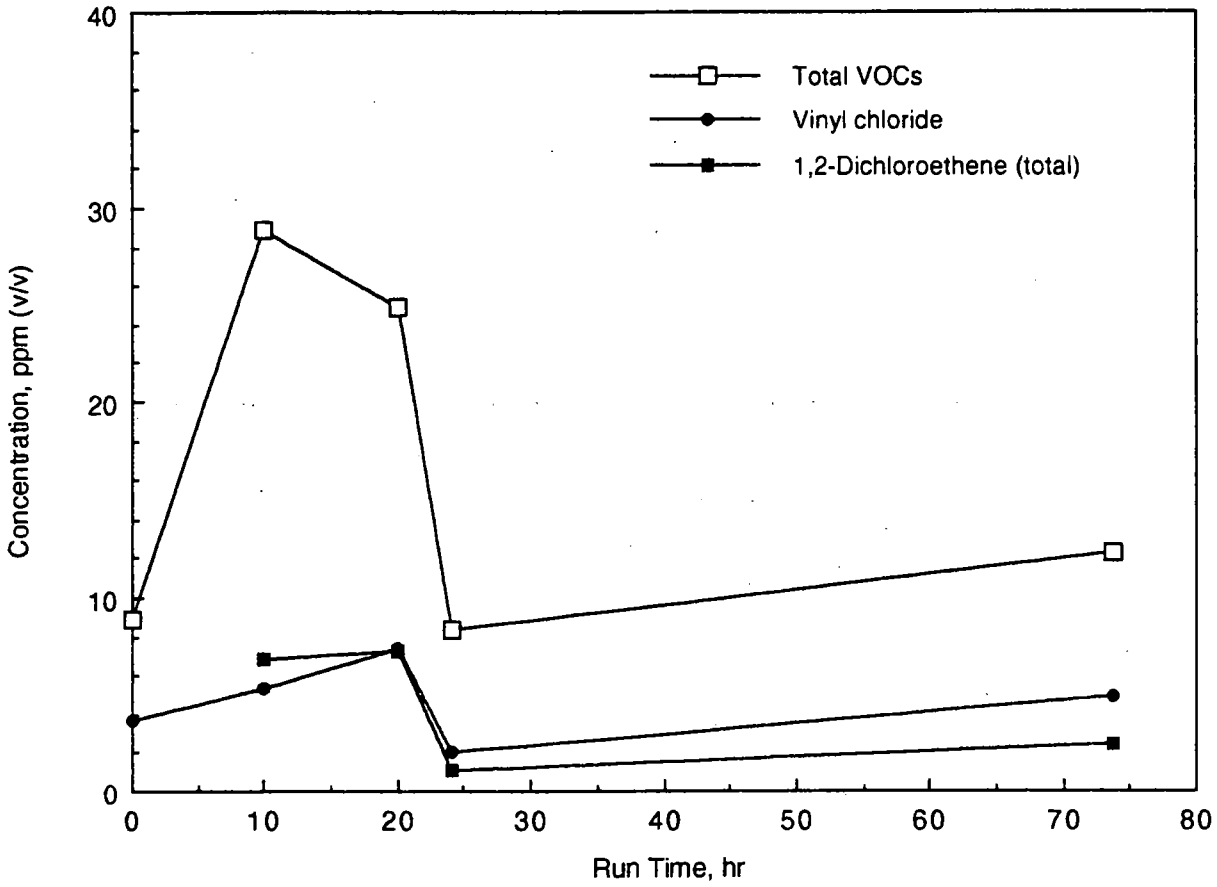


Figure 4-20. 75-Hour Test: Concentrations of Major Compounds and Total VOCs (excluding methane) for Probe EP-12 Gas Samples versus Run Time

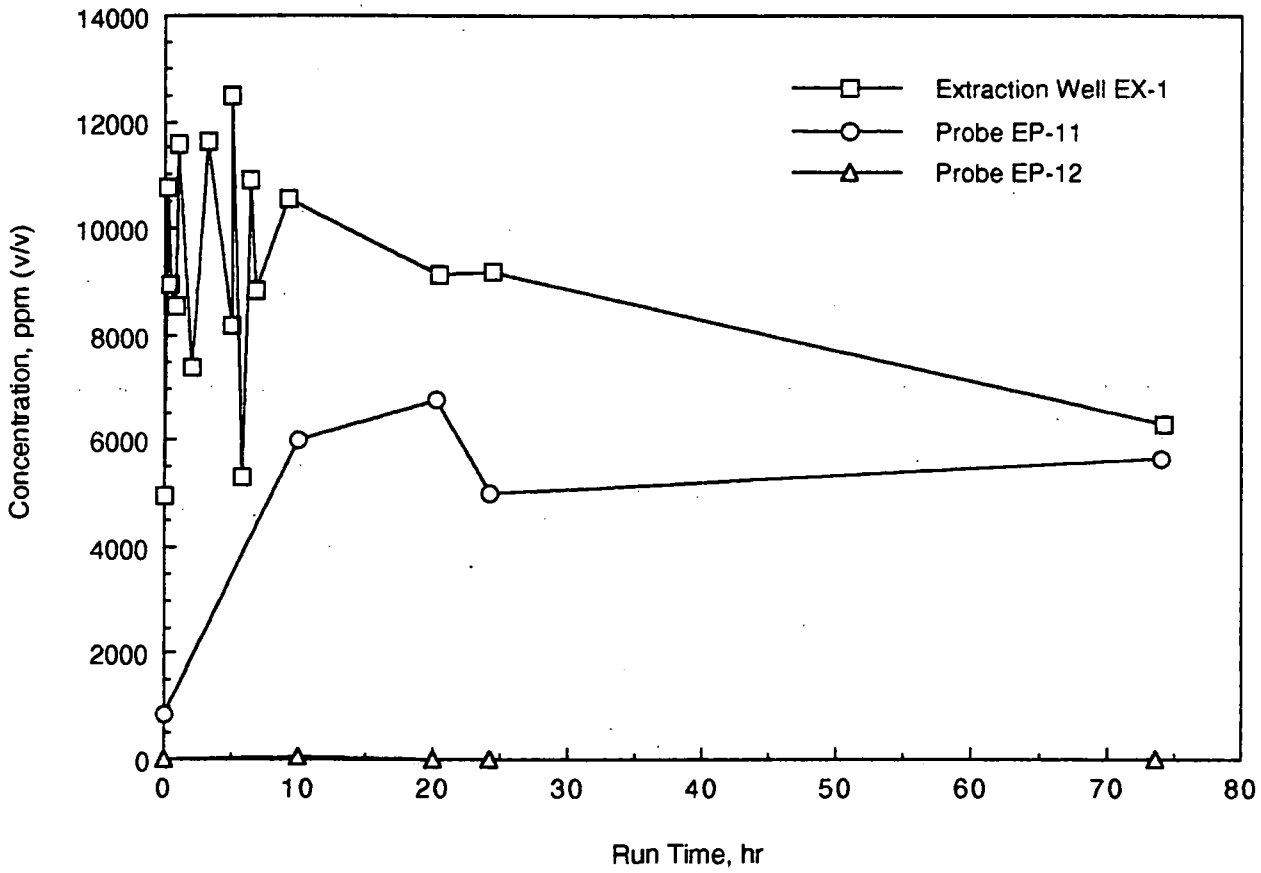


Figure 4-21. 75-Hour Test: Concentrations of Total VOCs (excluding methane) from Extraction Well EX-1 and Probes EP-11 and EP-12 versus Run Time

volatile organic molecules in the extracted gas stream will need to be considered in any future full scale system design, especially in the areas of safety and off gas treatment prior to discharge to the environment.

The chemical specific analyses of the extracted gas streams taken at the extraction wells and monitoring probes indicate a similar menu of constituents throughout the fill. These data may not necessarily be representative of all conditions under the cap. This residual uncertainty should be addressed during the full scale design phase.

The general trend in VOC concentration at the extraction well was downward during the 75 hours of continuous operations. Steady state had not, however, been reached. This conclusion is based upon the calculations provided later in this section.

A review of the behavior of the vacua at various locations under the cap indicates that the landfill is not air tight and some air is being introduced (presumably) through the perimeter. Also, per Figure 4-7, there is a relatively rapid loss of vacuum at the extraction well, passive vent, and monitoring probes upon the termination of testing when the blower was turned off. A rough estimate of the porosity of the system cannot be made from the vacuum/flow behavior at the extraction well and probes because there appears to be air leaking in around the edges of the landfill (see Section 5.0).

A porosity of 30 percent has been routinely used at other sites. Given the approximate volume of the site of 149,000 m^3 (750 feet long x 350 feet wide x 20 feet deep or 5.25×10^6 cubic feet), a pore volume of 45,000 m^3 can be estimated. Therefore approximately 0.20 of a pore volume was removed during the 75 hour testing in which 9,140 standard m^3 of gas was removed.

Based upon the temperature data collected and the continuous air stream opacity monitoring, it would seem that the potential for fire (or incipient fire) does not appear to be high. This information can also influence aspects of the full scale remedial design.

4.2 8-HOUR PASSIVE VENT TEST RESULTS

This section presents the results of the 8-hour passive vent test which was conducted March 29, 1992. A description of the equipment and materials used for the test is presented in Section 2.3; the test design is discussed in Section 3.2. As in the previous results section, the process data are presented first, followed by soil gas data. The first section contains a discussion of the results of the test as appropriate.

4.2.1 Process Data

Process data were taken during this test at the ISVS process trailer and at the monitoring points beneath the landfill cap at EX-1, EP-11, and EP-12. No data were taken at PV-2 because this passive vent was opened to the atmosphere, as were the other two passive vents (PV-1 and PV-3). The same parameters were measured for the passive vent test as for the 75-hour ISVS test (see Table 4-1). A computer-generated table, or spreadsheet, with all process data collected from each location is given as Appendix L; a similar spreadsheet is given as Appendix M for the field monitoring data collected during this test. These spreadsheets contain the date, time, and location of data recording, as well as the calculated parameters. The list of parameters calculated from the process data is the same as that given for the 75-hour test (see Table 4-2). The results presented in this section are from the data in the spreadsheets. The calculated flow rate and volume data are presented first. Vacuum, pressure, and temperature data are presented next. The field monitoring data pertaining to chemical monitoring are discussed in Section 4.2.2.1.

4.2.1.1 Flow Rate and Volume Data. The extracted gas flow rate was calculated using the equation given in Section 3.3.2.1 with the appropriate pitot tube data presented in Appendix L. Figure 4-22 shows the extracted gas flow rate in std m^3/min and scfm as a function of testing time. Because ambient bleed-in air was introduced into the extraction gas upstream of the blower (downstream of the extraction well) in order to meet the minimum flow requirement of the blower, it was necessary to calculate the total gas flow rate through the blower and carbon unit by summing the two flow rates. Figure 4-23 shows the total flow rate through the blower and carbon unit as well as the extracted gas and air bleed-in flow rates for the passive vent test as a function of run time. Bleed in air was needed when the extracted flow rate from the landfill was below system design parameters. Gas was

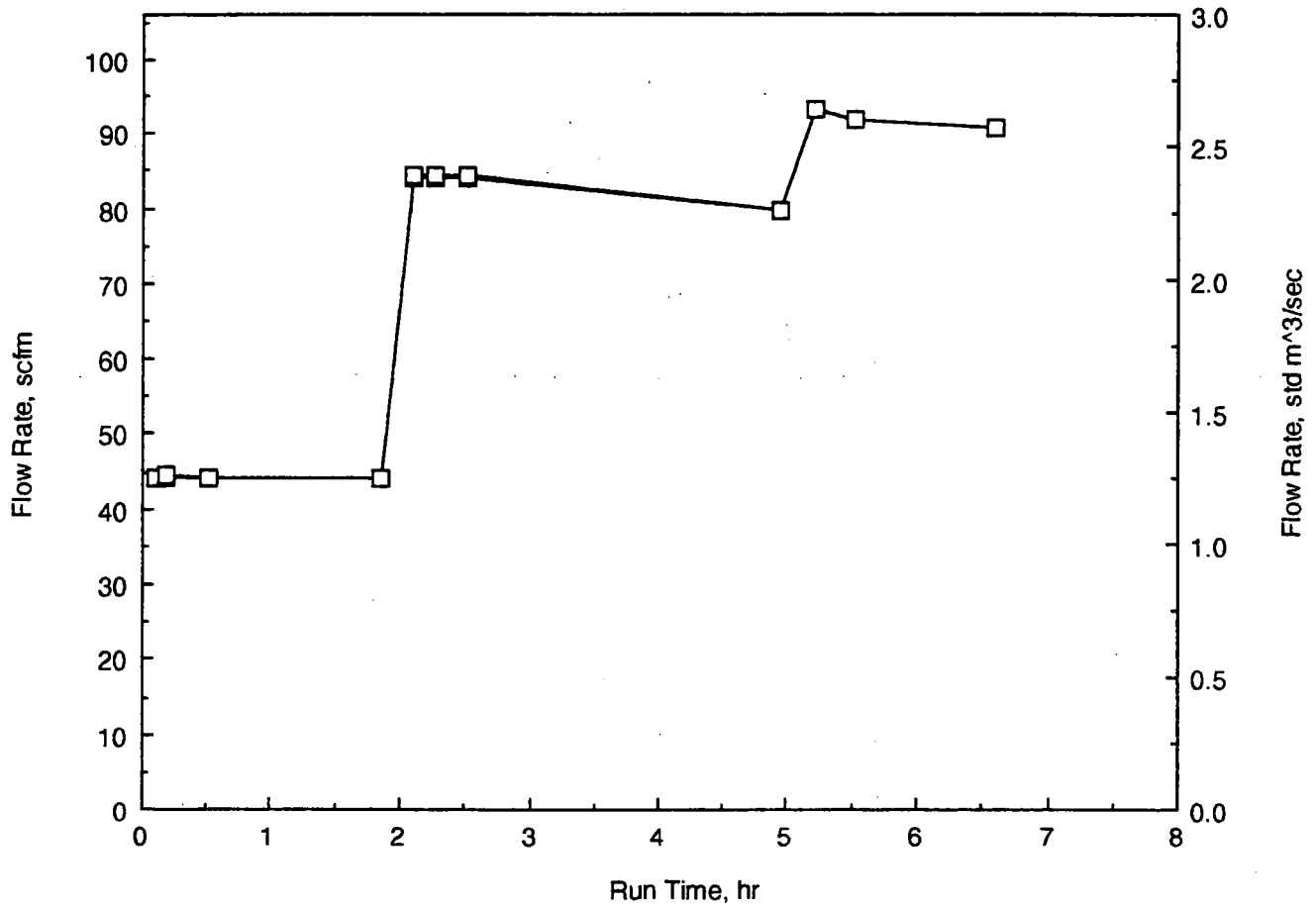


Figure 4-22. Passive Vent Test: Extracted Gas Flow Rate versus Run Time

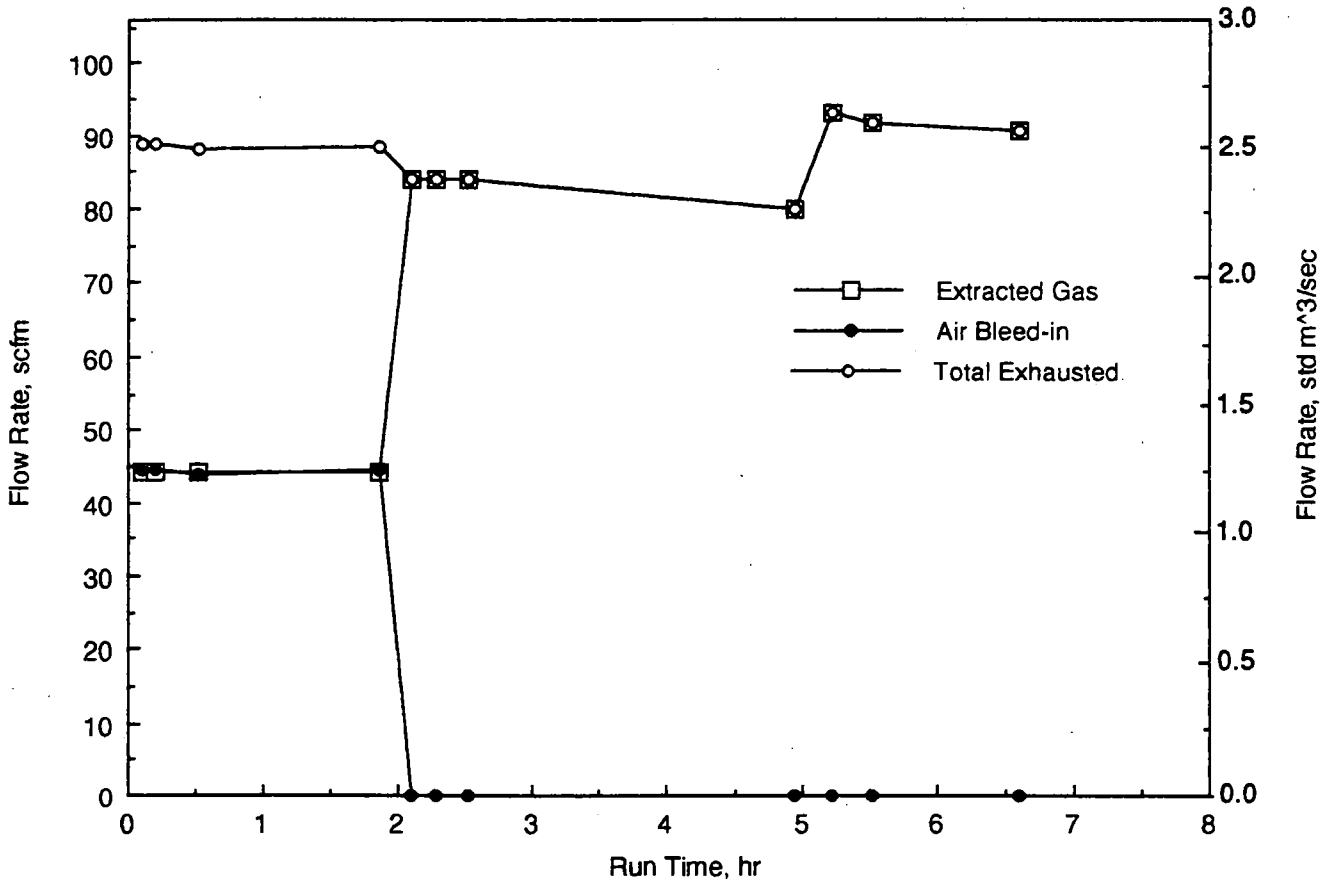


Figure 4-23. Passive Vent Test: Gas Flow Rates versus Run Time

extracted from the landfill at a flow rate of approximately 45 scfm for the first 2 hours of the test (the target was 50 scfm). The flow rate of the extracted gas was then increased to approximately 85 scfm (the target was 100 scfm) and gradually tapered off to about 80 scfm between the run times of 2 and 5 hours. At approximately two hours into the test, the air bleed-in flow rate was reduced to zero. A maximum flow rate was achieved for the gas from the landfill at about 5.5 hours. This flow rate ranged from 90 to 95 scfm for the duration of the test.

The cumulative volume of gas removed from the landfill during the test is presented in Figure 4-24. Figure 4-25 shows the cumulative volume of gas that went through the blower and carbon unit. The volumes were calculated by multiplying flow rate by elapsed time between specific sampling times during the test and adding the volume from each time step to compute the cumulative volume. The actual numbers used for the calculation and the calculated values are presented in Appendix L. For the passive vent test, the total volume removed from the landfill was approximately 29,000 std ft^3 (or 821 std m^3). The volume of ambient bleed-in air that was introduced during the first 2 hours of the test was approximately 5,300 std ft^3 (or about 150 std m^3). These two volumes were combined to produce a total volume of gas through the blower and carbon unit of approximately 34,000 std ft^3 (or 963 std m^3). Thus the volume of bleed-in air was only about 15 percent of the total volume through the blower. The extracted gas from the landfill accounted for about 85 percent of the total gas volume through the blower and carbon unit.

4.2.1.2 Vacuum and Pressure Data. Vacuum and pressure data were collected during the passive vent test at the mobile ISVS unit and from beneath the landfill cap at the extraction well EX-1 and monitoring probes EP-11 and EP-12. The data collected at the mobile ISVS unit are presented in Appendix L. The majority of the vacuum and pressure data collected at the mobile ISVS unit are related to evaluation of the mobile unit operation. The vacuum data collected beneath the landfill cap reflected the response of the landfill to the operating conditions produced by the mobile ISVS unit and the open passive vents. The vacuum data in the landfill during the test are presented first, followed by the various vacuum and pressure data measured or calculated for the mobile unit operations.

Figure 4-26 shows the vacua measured at the extraction well and process trailer during the test. The vacua measurements at the process trailer were taken at the

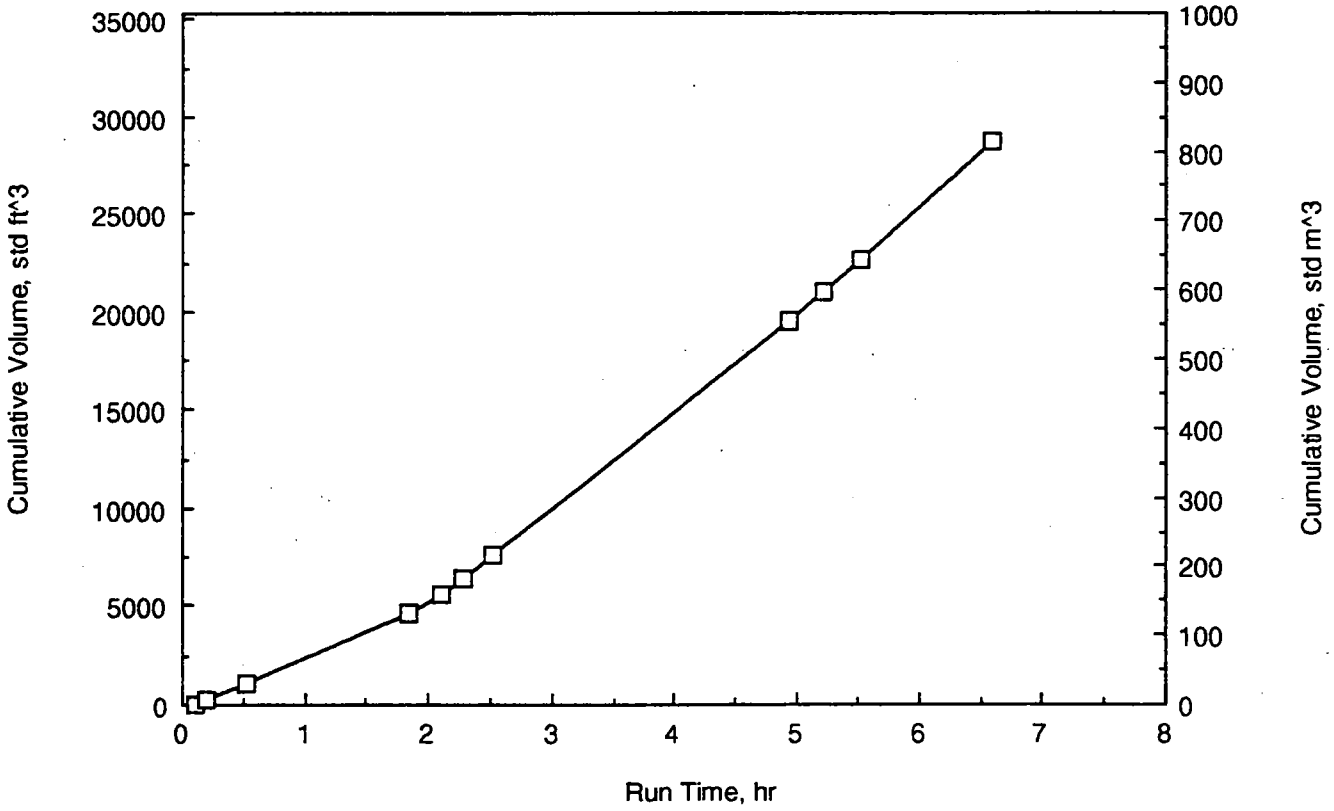


Figure 4-24. Passive Vent Test: Cumulative Volume of Gas Removed from Landfill versus Run Time

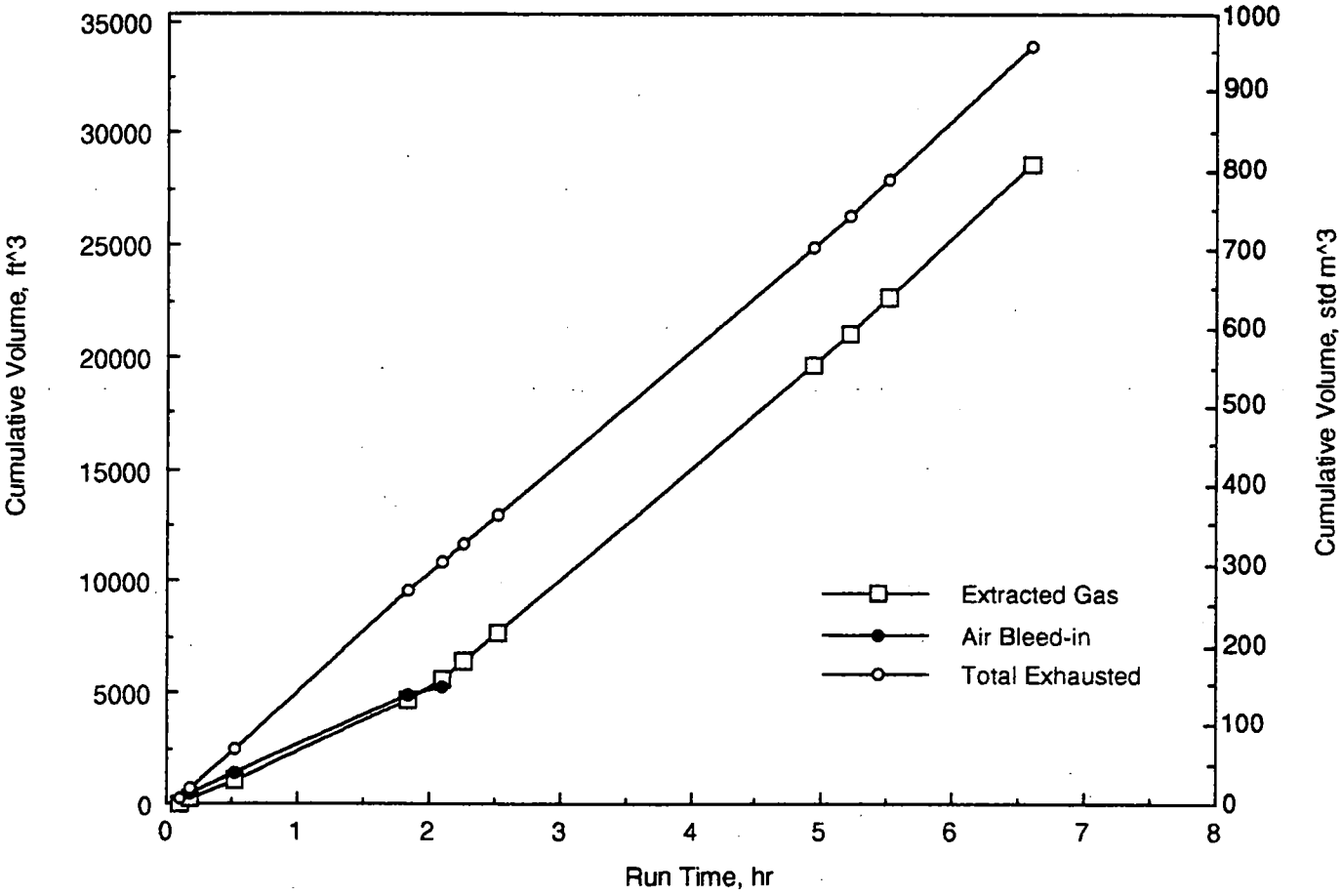


Figure 4-25. Passive Vent Test: Cumulative Volume of Gas Through Blower and Carbon Unit versus Run Time

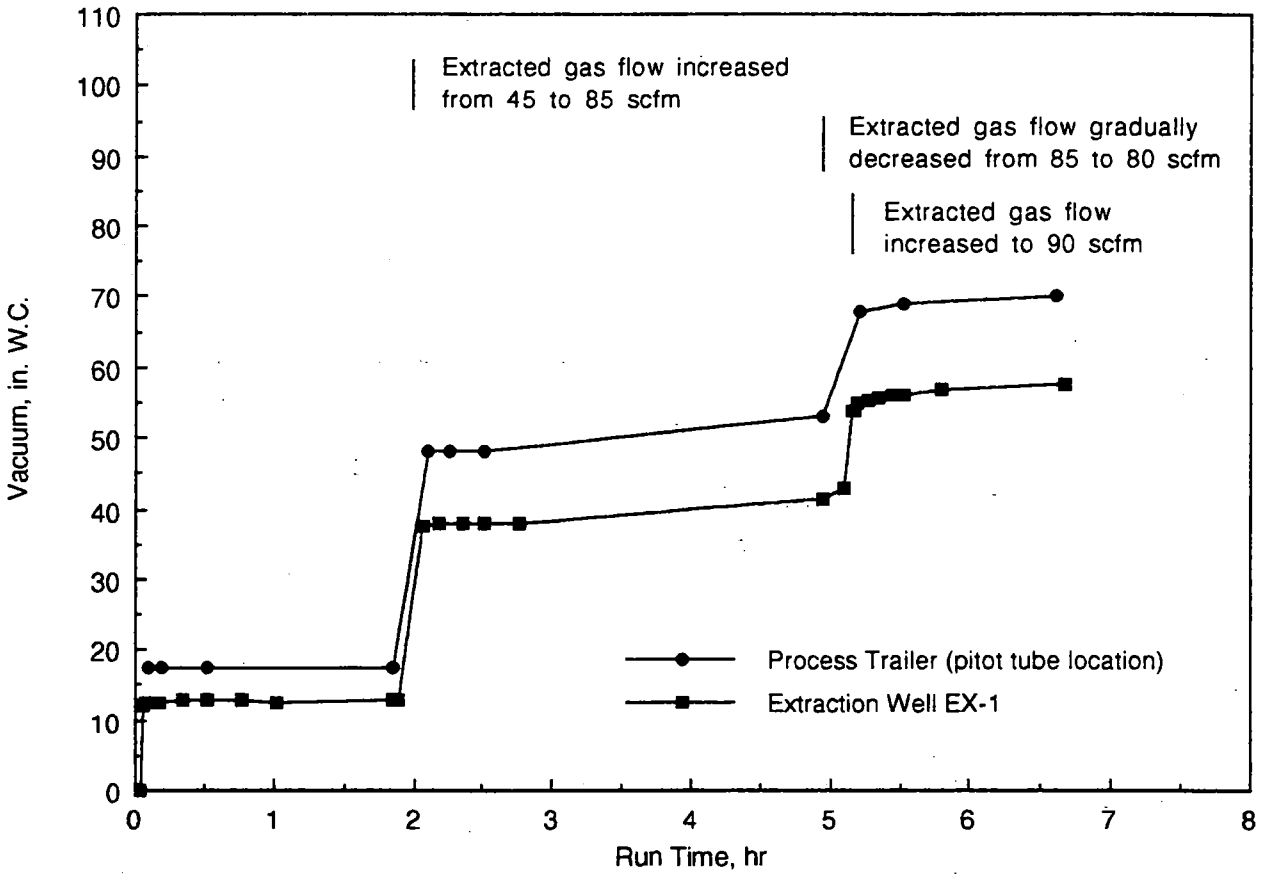


Figure 4-26. Passive Vent Test: Vacua at Extraction Well EX-1 and Process Trailer versus Run Time

pitot tube location. Figure 4-27 shows the vacua measured at probes EP-11 and EP-12 during the test. These data showed general increases corresponding to the extracted gas flow rate increases (refer to Figure 4-22). No vacuum data were collected at PV-2 because, by design, it was open to the atmosphere during this test. The captions at the tops of the figures indicate the extracted gas flow rate events during the test. The vertical lines mark the end of the flow condition described by the text to the right of each line. The vacuum at the extraction well increased from 0 to 13 in.W.C. during the first flow rate period (extracted gas flow rate of about 45 scfm). When the extracted gas flow rate was increased to 85 scfm, the vacuum at EX-1 increased to approximately 38 in.W.C. The vacuum at EX-1 increased to 56 in.W.C. when the extracted gas flow rate was increased to 90 scfm. The vacuum at EX-1 was still increasing slowly when the test was ended. Comparison of the vacuum at EX-1 with the vacuum at the process trailer shows the pressure drop in the extraction pipe between the extraction well and the process trailer. One can see from Figure 4-27 how similar the behavior of the vacua at EP-11 and EP-12 were. A comparison of the curves in Figures 4-26 and 4-27 shows that the behavior of the vacua created at EP-11 and EP-12 followed that at EX-1, but with a slight time lag.

The various vacua and pressures measured or calculated for the mobile ISVS unit are presented in graphical form in Figures 4-28 and 4-29. The vacuum at the pitot tube was relatively low (17 in.W.C) compared to the blower inlet vacuum (65 to 75 in.W.C.) during the first two hours of operation (see Figure 4-28). This difference was due to the significant amount of ambient air bleed-in that was used during this time period (refer to Figure 4-23). Air bleed-in was discontinued completely at about two hours run time. The vacuum at the pitot tube remained lower than the blower inlet vacuum after the air bleed-in was terminated. For the time period (without bleed-in) between 2 and 5 hours run time, the pitot tube vacua ranged from 48 to 53 in.W.C. while the blower inlet vacua stayed approximately at 75 in.W.C.. Vacuum data for both the pitot tube location and the blower inlet were essentially the same for the duration of the test ranging between about 69 and 72 in.W.C. The vacuum data at the pilot tube and blower inlet were essentially the same because the blower was operating at maximum flow rate. The differential pressure across the carbon unit (Figure 4-29) was quite low for the duration of the passive vent test, never exceeding 2.3 in.W.C. differential. This is well below the pressure drop of 30 in.W.C. at the design flow rate of 1,000 cfm. The carbon unit differential pressure showed only very slight buildup during the test. Significant buildup would

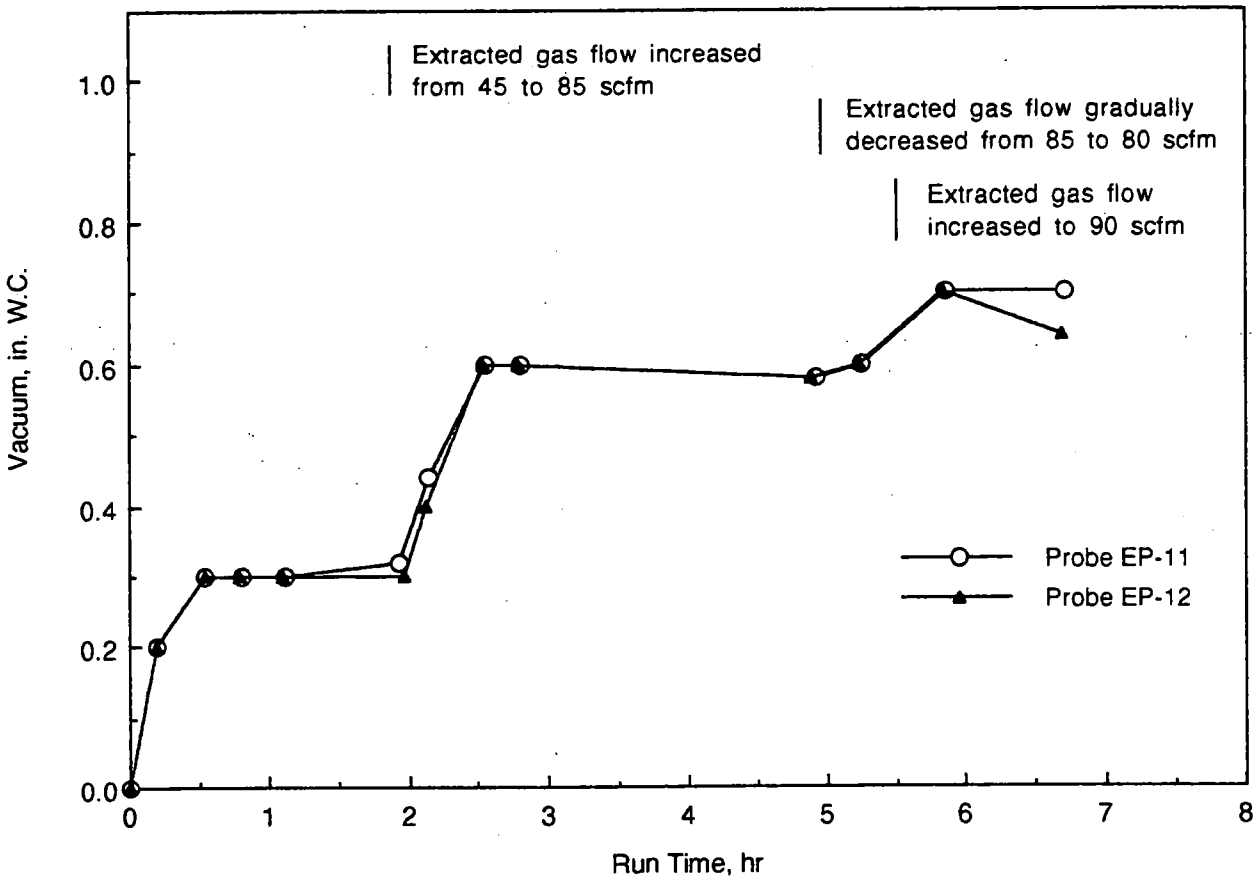


Figure 4-27. Passive Vent Test: Vacua at Probes in Landfill versus Run Time

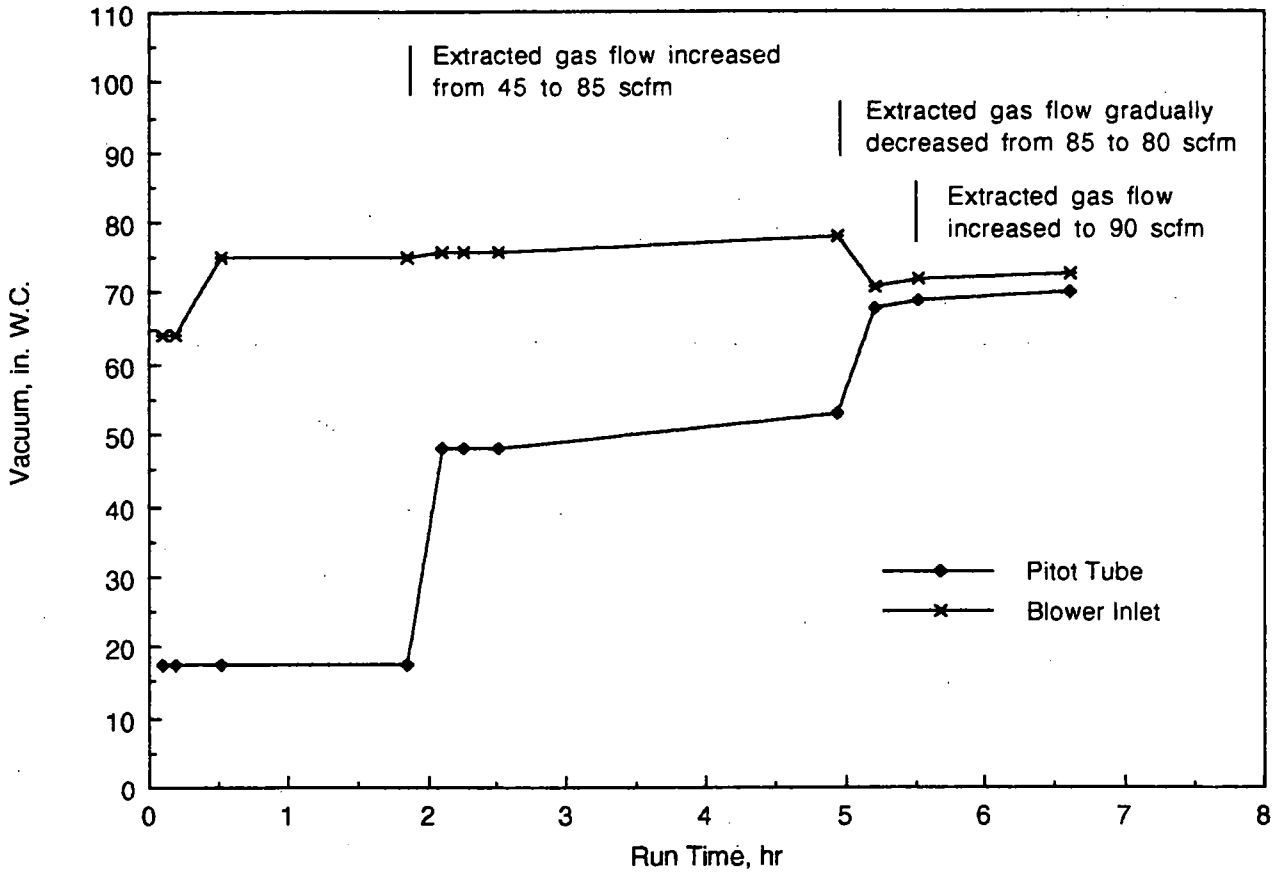


Figure 4-28. Passive Vent Test: Process Vacua at Pitot Tube and Blower Inlet versus Run Time

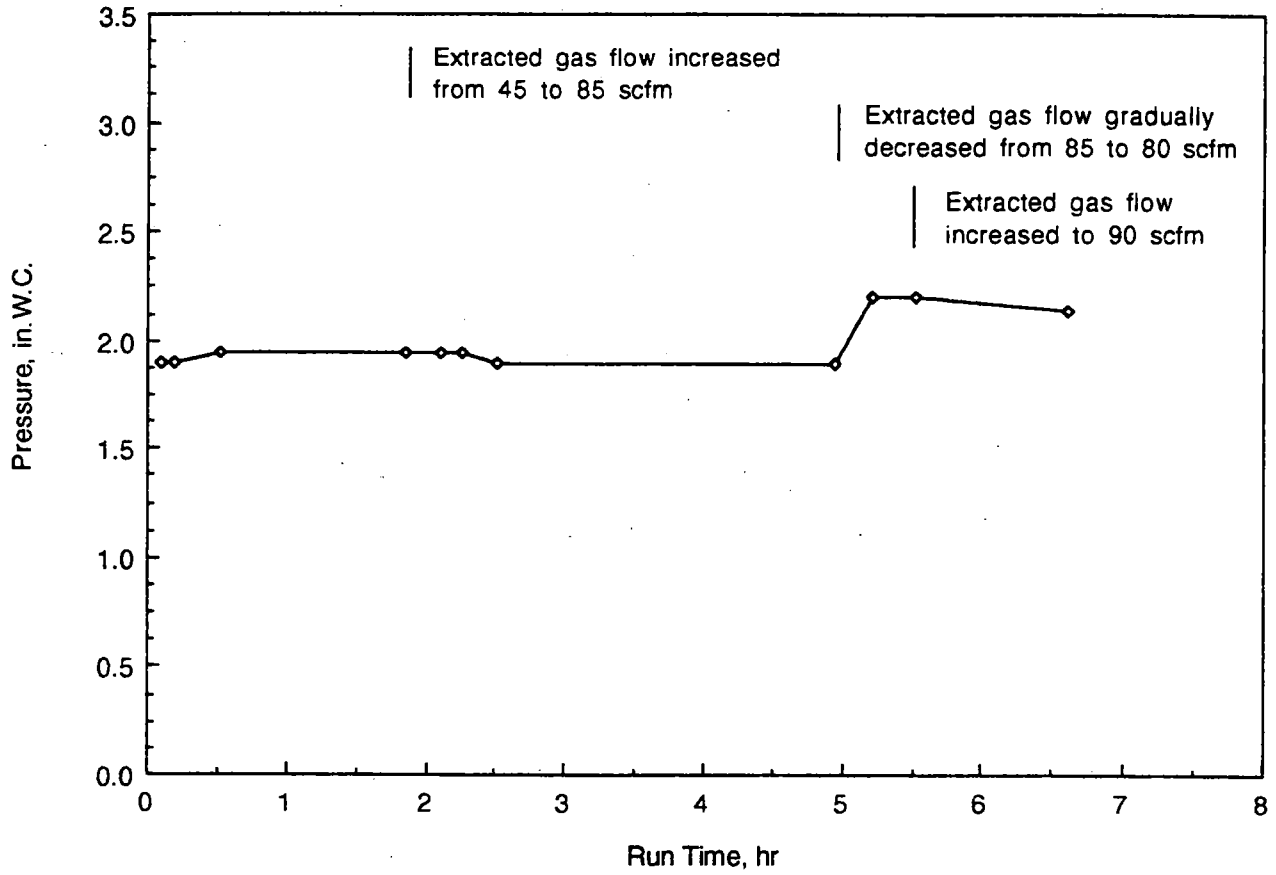


Figure 4-29. Passive Vent Test: Carbon Unit Differential Pressure versus Run Time

have been an indication of the collection of water condensate or of general loading. The differential pressure fluctuations were directly related to the total exhaust flow rate (compare Figure 4-29 with Figure 4-23).

4.2.1.3 Temperature Data. Temperature data were collected from beneath the landfill cap and at the process trailer during the 8-hour passive vent test. The temperature data from the landfill cap are presented in tabular form in Appendix M and in graphical form in Figure 4-30. In general, the changes in temperature at EP-11 and EP-12 followed those at EX-1. The temperatures ranged between about 6 and 7.5°C (42.8 and 45.5°F) for the extraction well gas. The temperatures measured at EP-11 were about 1°C lower than those at EX-1; the temperatures measured at EP-12 were about 2°C higher than those at EX-1. The temperature data measured beneath the landfill cap should be considered approximately correct because, during the course of the test, some difficulty was encountered with the hand-held temperature read-out unit due to the inclement weather conditions. However, the temperature data given for the process trailer are considered more accurate. The temperature data from beneath the cap do show that no thermal buildup occurred within the landfill as the initial anaerobic condition became more aerobic as air was drawn in from the outside. Significant temperature increase could be an indication of incipient fire. This was a potential concern of using ISVS at the Lord-Shope landfill site.

The temperatures measured at the process trailer are given in Appendix L and in Figures 4-31 and 4-32. (The comparable figure for Figure 4-31 is Figure 4-12 for the 75-hour test.) For the passive vent test, the demister inlet temperature was monitored as the temperature at the process trailer because the pitot tube temperature sensor was not working. Comparison of the two curves in Figure 4-31 shows the temperature increased from EX-1 to the process trailer. Although the ambient temperature was not measured due to the failure of the thermocouple, the National Weather Service reported a high of 7.7°C (46°F) for the day of this test. Therefore, the fact that the temperature was higher at the process trailer could be explained based on ambient temperature. Demister inlet, blower discharge, blower differential, and carbon exhaust temperatures are shown in Figure 4-32. The blower discharge temperature was significantly higher than the inlet temperature (differential ranged from about 12 to 27°C or 53.6 to 80.6°F) due to the adiabatic heat of compression induced by the blower. This reduced the gas stream humidity

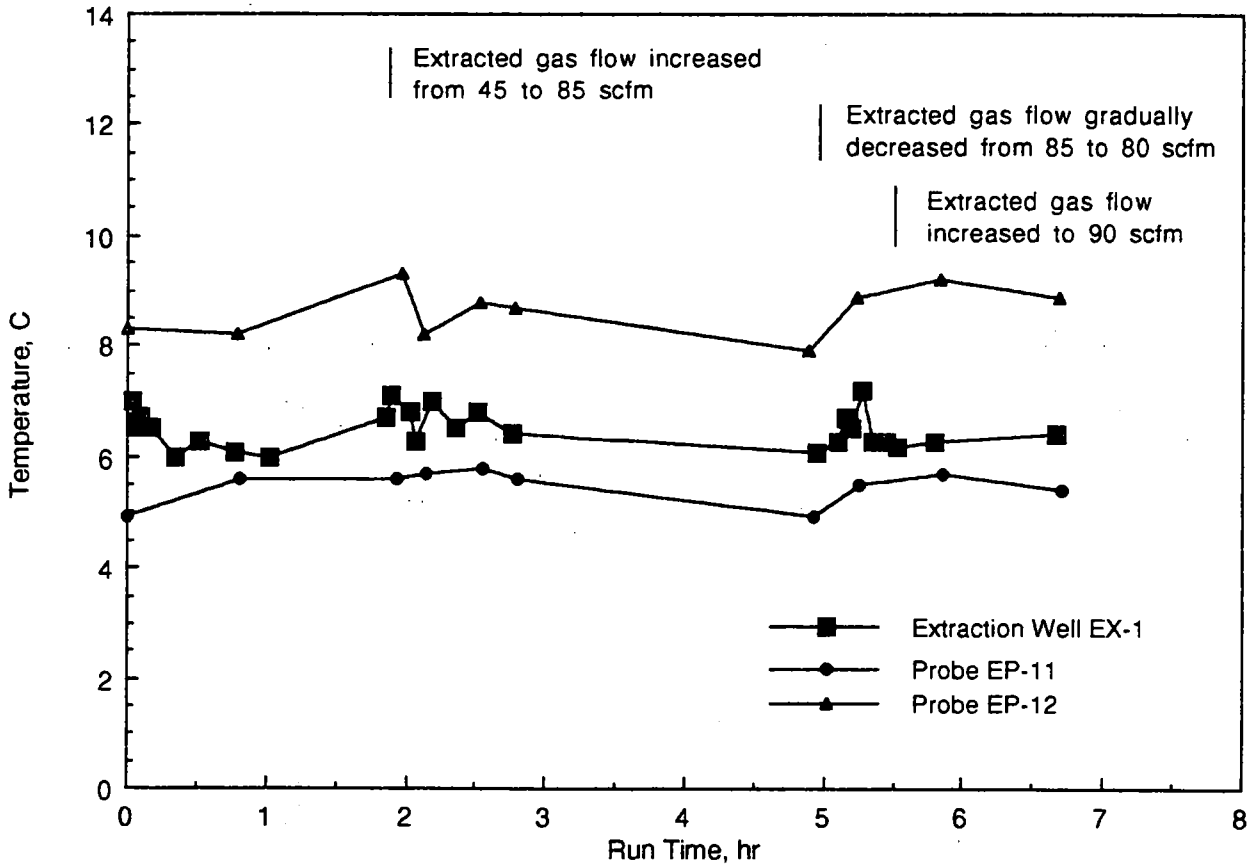


Figure 4-30. Passive Vent Test: Temperatures in Landfill versus Run Time

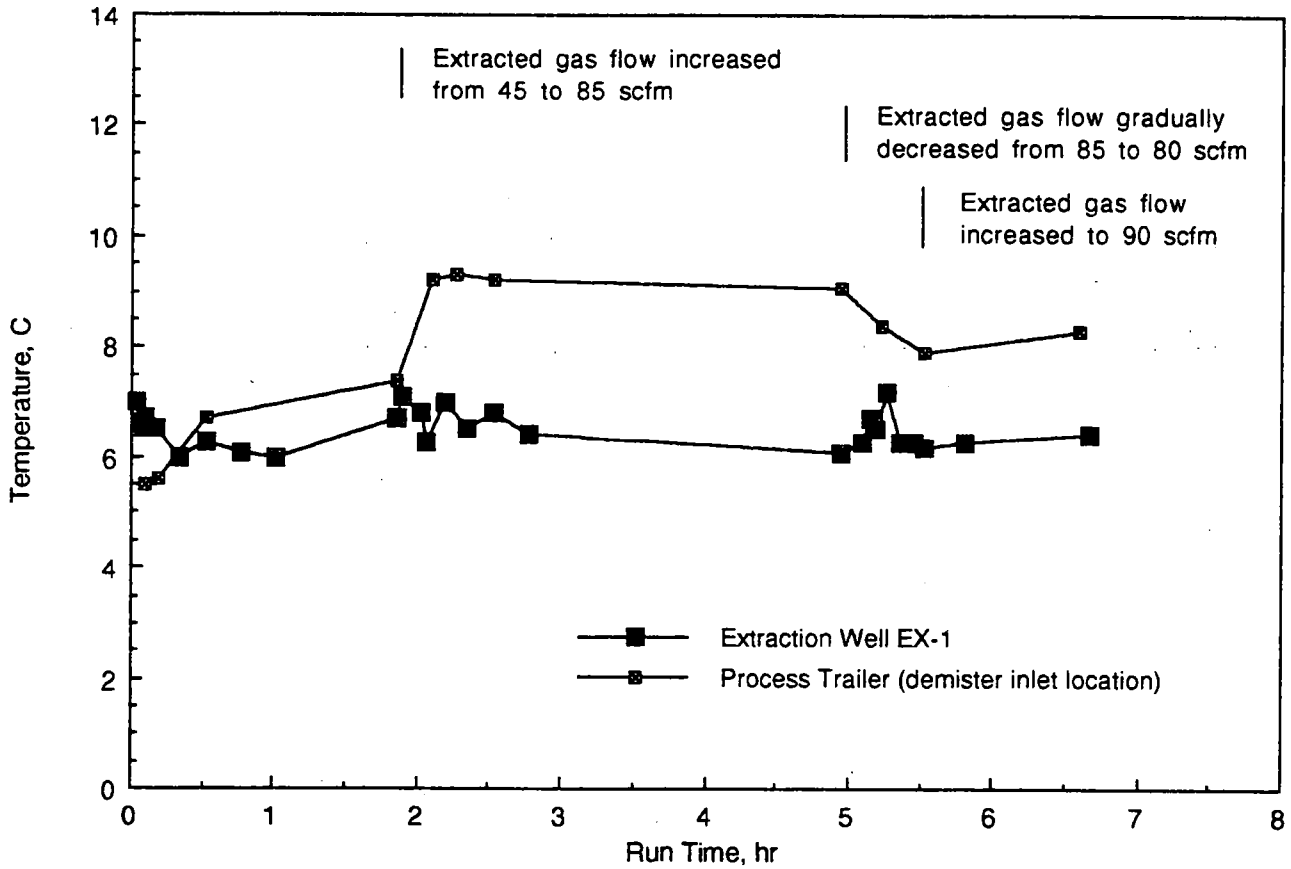


Figure 4-31. Passive Vent Test: Temperatures at Extraction Well EX-1 and Process Trailer versus Run Time

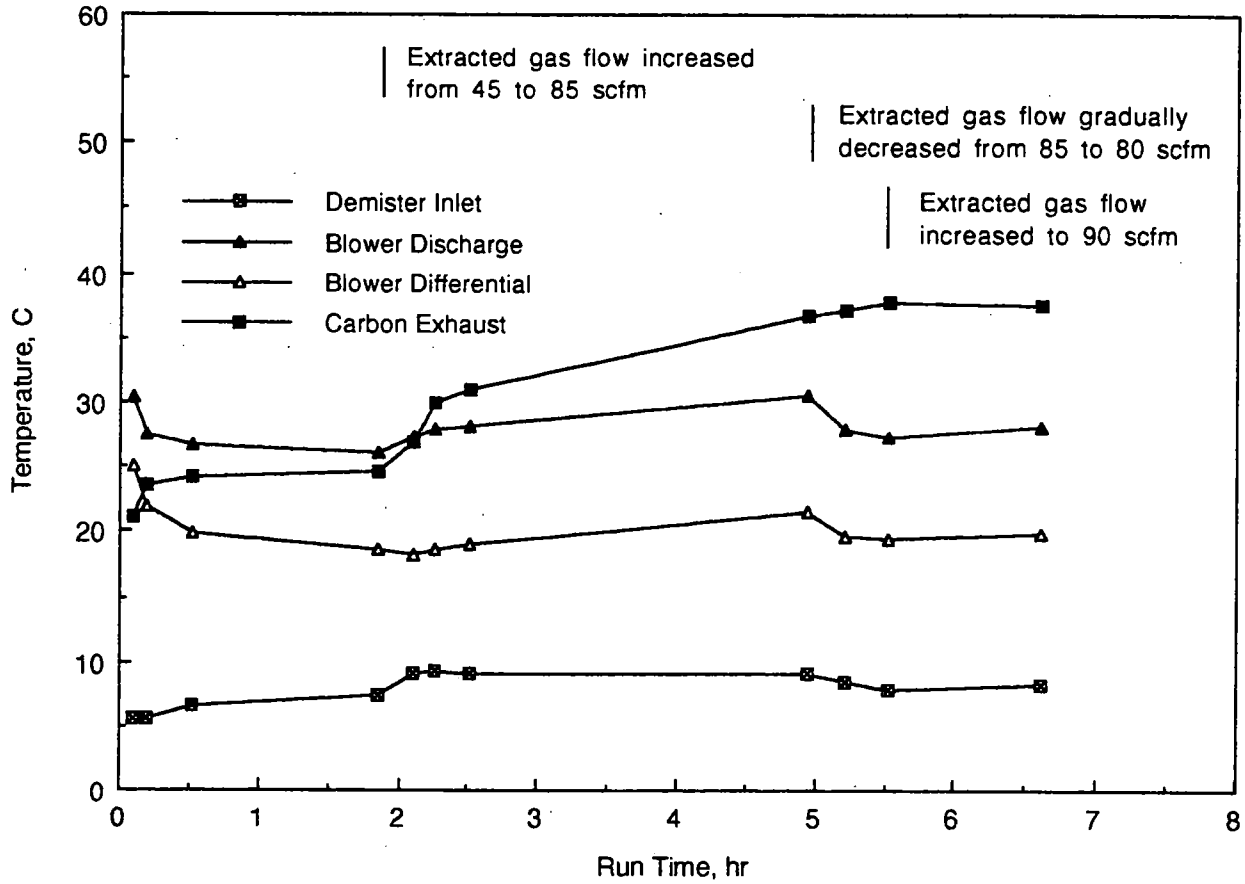


Figure 4-32. Passive Vent Test: Temperatures at Process Trailer versus Run Time

prior to treatment by the activated carbon. The temperature also increased somewhat across the carbon bed (compare blower discharge and carbon exhaust temperature in Figure 4-32) due to the heat of adsorption of the vapor phase organic contaminants as they were removed by the carbon.

4.2.2 Soil-Gas Data

The soil-gas data collected during the 8-hour passive vent test consisted of field monitoring data measured with various hand-held gas monitoring instruments and of chemical-specific data from laboratory analysis of gas samples taken during the test. Soil-gas data were taken at the extraction well and carbon unit exhaust. No soil gas data were taken at any of the probes on the landfill cap. All discussion of results of carbon exhaust monitoring/sampling is presented in Section 4.5.1. Because the passive vent test was a rather short one, only a few sampling events were scheduled. Soil gas data were taken immediately before each flowrate increase and at the end of the test. The passive vent test was more targeted towards vacuum/flow data generation in an effort to evaluate further the nature of the landfill (i.e., help answer the question of air tight vs. air permeable).

4.2.2.1 Field Monitoring Data. Field monitoring data were collected at the extraction well with hand-held monitoring instruments in the same manner as for the 75-hour test. The monitoring times and locations are given in Appendix M. Table 4-6 presents a summary of the field monitoring data. The OVA readings exceeded the capacity of instrument in all cases. The HNu data showed an increase in VOC concentration during the course of the test, however, when these values are compared to the chemical-specific data presented in the next section, the same phenomenon seems to be occurring as in the 75-hour test. The HNu showed an increase in concentration, but the chemical-specific data showed an opposite trend. The same explanation given in Section 4.1.2.1 applies here. As the explosimeter data show, the percent methane content the extracted gas was still high and most likely caused quenching of the HNu photoionization detector response.

4.2.2.2 Chemical Specific Data. Chemical specific data have been produced from analyses of gas samples collected in Tedlar® bags during the passive vent test at the extraction well EX-1 and at the carbon exhaust. All data pertaining to the activated carbon usage and performance are given in Section 4.5.1. Tedlar® bag samples

TABLE 4-6

FIELD MONITORING DATA COLLECTED AT EXTRACTION WELL DURING PASSIVE VENT TEST

Sampling Time[a] (hour)	Monitoring Instrument		
	OVA[b] (ppm)	HNu[c] (ppm)	Explosimeter (% LEL)
2.02	>1,000	420	NA[d]
5.09	>1,000	460	NA
6.77	>1,000	580	45
7.27	>1,000	640	52

[a]Time measured from beginning of test.
[b]Organic Vapor Analyzer.
[c]Gas monitor with photoionization detector.
[d]Data not available.

were analyzed for methane (analysis according to method described in Appendix J) or the list of chemicals in Table 2-4 (analysis according to modified Method TO-14, see Section 2.4.2). Summary data sheets have been produced for each sample analyzed by modified Method TO-14. The raw data for all samples as supplied by the analytical laboratories are archived in-house (ECKENFELDER INC.) and are available upon request. The summary data sheets are provided in Appendix N. Each data sheet has the sample number, analysis date, and analytical laboratory listed at the top of the page. The body of the summary data sheets lists the chemicals on the analyte list, the concentrations reported, comments as appropriate, dilution factors, and total VOC concentrations. The last line in the table gives the sampling time. The results of the methane-specific analysis of all samples taken during Part 2 Testing are included as Appendix J.

Table 4-7 shows the concentrations of the major organic compounds reported for gas samples collected at the extraction well during the passive vent test. Only the concentration of total VOCs, vinyl chloride, 1,2-dichloroethene (total), and methane are shown. The summary data sheets for samples EX-22, EX-24, and EX-26 are given as Appendix N. Figure 4-33 is a graphical representation of the data presented in Table 4-7; methane is not included. Vinyl chloride and 1,2-dichloroethene (total) account for 81 to 84 percent of the VOCs reported above the limit of quantitation, LOQ. During the test, the concentrations of total VOCs and vinyl chloride decreased slightly; the concentration of 1,2-dichloroethene (total) increased from between the sampling times of 1.85 to 5.09 hours, but then decreased slightly by the sampling time of 6.77 hours. In reality, the changes shown in these concentrations are essentially insignificant given the inherent variability in soil gas sample collection and analysis. The test would have to be longer to develop information on concentration trends. This, however, was not the purpose of the passive vent test. The percent methane content in the extracted gas at the end of the test was somewhat lower than that reported at the end of the 75-hour test (4 percent as compared to the 7 percent for the 75-hour test). This may reflect the dilution by the ambient air flow through the open passive vents into the landfill, as well as the general continuing decrease in methane concentration, or a combination of both effects.

Figure 4-34 shows the total mass of VOCs and methane removed from the landfill during the test. Each compound that was detected above the LOQ is reported.

TABLE 4-7

CONCENTRATIONS OF MAJOR ORGANIC COMPOUNDS REPORTED FOR GAS SAMPLES COLLECTED AT THE EXTRACTION WELL DURING THE PASSIVE VENT TEST

Sampling Time[a] (hour)	Sample Number	Concentration			
		Total VOCs[b] ppm (v/v)	Vinyl Chloride ppm (v/v)	1,2-Dichloro-ethene (Total) ppm (v/v)	Methane % (v/v)
1.85	EX-22	7,500 (84)[c]	3,300	3,000	
5.09	EX-24	7,200 (83)	2,500	3,500	
6.77	EX-26	6,900 (81)	2,300	3,300	
6.77	MEX-06A				4

[a]Time measured from beginning of test.
[b]Total VOCs include all compounds reported by Lord Corporation Laboratory above the LOQ; does not include methane.
[c]Number in parentheses gives the percent of total VOCs contributed by vinyl choride and 1,2-dichloroethene (total).

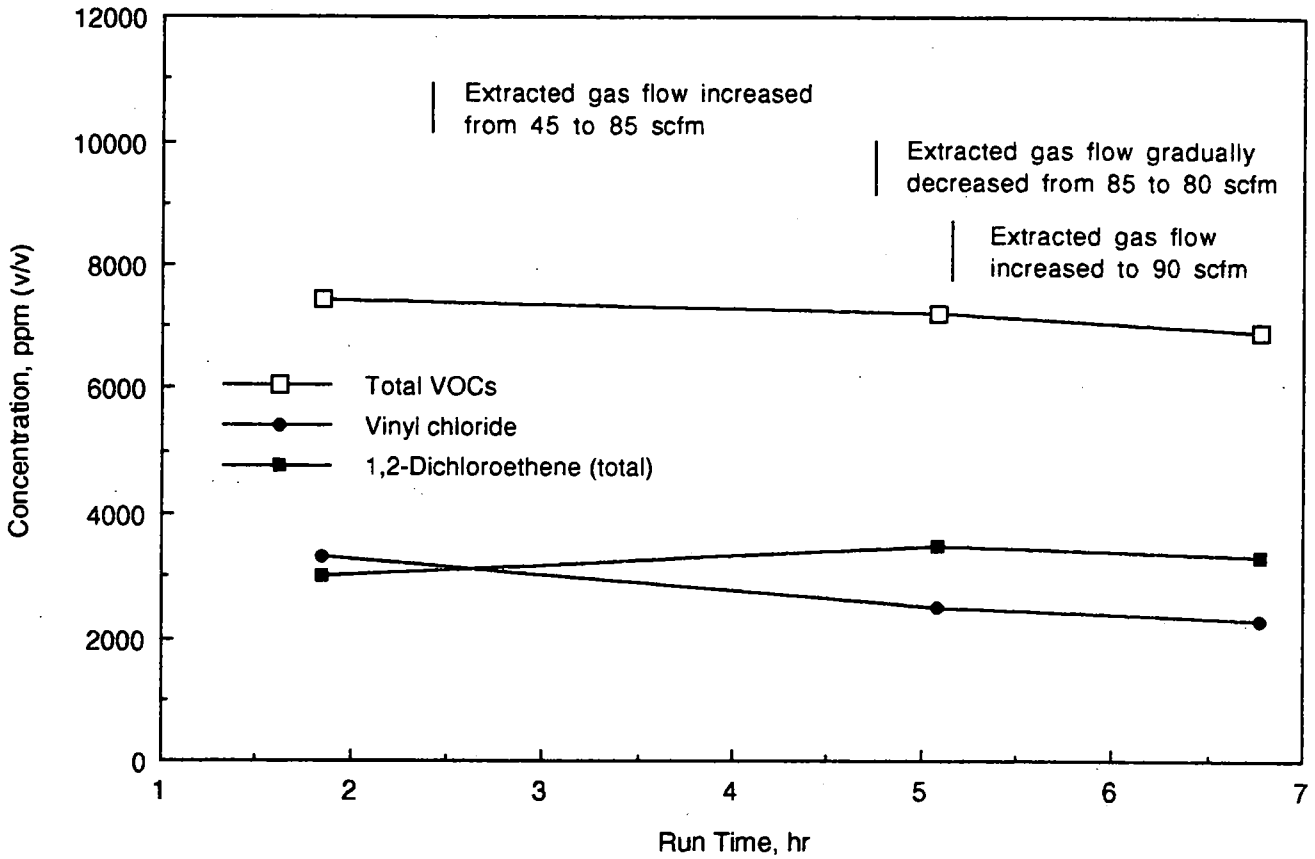


Figure 4-33. Passive Vent Test: Concentration of Major Compounds and Total VOCs (excluding methane) for Extraction Well EX-1 Gas Samples versus Run Time

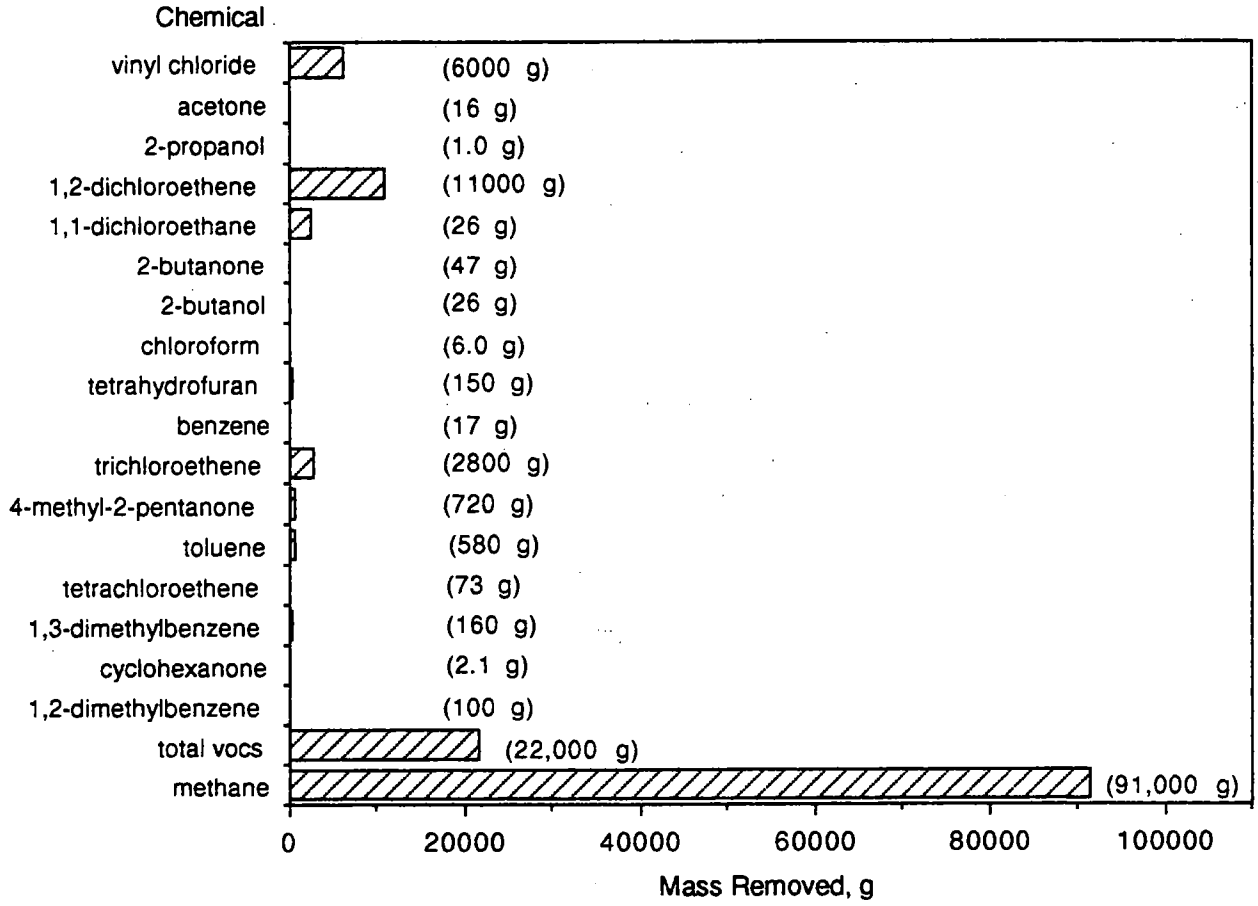


Figure 4-34. Passive Vent Test: Total Mass of Compounds Removed from Extraction Well EX-1

Approximately 91 kg methane and 22 kg total VOCs were removed. The total mass of each compound removed was calculated from chemical specific data and process data given in Appendices N, L, and M. An example of the calculation of total mass removed and any assumptions made are included in Appendix K (calculations were similar to those for 75-hour test). The comparison of the compounds identified in the 75 hour vs. passive vent tests indicates that qualitatively, the lists are identical, i.e., each compound identified in the samples from the extraction well during the 75 hour test was identified in samples taken from the extraction well during the passive vent test.

4.2.3 Discussion of Results

A review of the vacuum data generated by the three passive vents configuration for the extraction well and monitoring probes indicates a surprisingly high percentage of "isolation" by this geometry. Based upon the data generated during the test, a percent isolation of 97 percent can be estimated. The percent isolation reflects how well the passive vent configuration eliminates the influx of air from the surroundings, i.e., other than from the passive vents themselves.

If a passive vent configuration were to be required for full scale remediation, it could be a viable option based upon these test results. A passive vent configuration could be required if continued vapor stripping on this or any system resulted in an increase in vacuum and a reduction in flow rate. This behavior reflects a system encountering difficulty in vapor stripping because air is not being introduced at a sufficient rate to maintain the design parameters for vacuum extraction. Thus, another source of air must be provided.

A total of 29,000 standard ft^3 (or 821 standard m^3) of air was removed during the 7.5 hours of testing. A total of 113 kg of VOCs including 91 kg of methane was removed. The concentration of methane exhibited the most dramatic decrease as the relatively small volume prescribed by the passive vents (600 m^3 or 21,000 ft^3) was continuously stripped. Approximately 4.5 pore volume exchanges occurred using a 30 percent porosity.

4.3 PULSE/SLUG TEST RESULTS

This section presents the results of the pulse/slug tests which were performed March 31 through April 2, 1992. These tests will be referred to as the slug tests hereafter. The data are presented as either process data or chemical data. A discussion of the equipment and materials used for these tests is presented in Section 3.3.1; a description of the tests is given in Section 3.3.3.

4.3.1 Process Data

Process data were taken during the slug tests at the ISVS Mobile Unit (also called the process trailer) and at the monitoring points beneath the landfill cap at EX-1, PV-2, EP-11, and EP-12. Unlike in the 75-hour test and the 8-hour passive vent test, the process data collected at the process trailer consisted only of the data needed to calculate the flow rate of gas, either injected or extracted. These data were the barometric pressure and the vacuum, temperature, and differential pressure at the pitot tube. A computer-generated table, or spreadsheet, with all process data collected from each location is given as Appendix O; this spreadsheet also contains the field monitoring data collected during this test. These spreadsheets contain the date, time, and location of data recording, as well as the calculated parameters. The parameters calculated from the process data were the injected or extracted gas flow rates, absolute pressure, and total volumes of injected and extracted gas. Each slug test is treated separately in these calculations. The calculations are according to the description given in Section 4.1.1 for the 75-hour test. The results presented in this section are from the data in the spreadsheets. The calculated flow rate and volume data are presented first. Vacuum, pressure, and temperature data are presented next. The field monitoring data pertaining to chemical monitoring are discussed in Section 4.3.2.1.

4.3.1.1 Flow Rate and Volume Data. Both the injected gas and extracted gas flow rates were calculated using the equation given in Section 3.3.2.1 with the appropriate pitot tube data presented for each slug test in Appendix O. Table 4-8 shows the calculated flow rates and volumes of injected and extracted gas for each of the slug tests. Slug tests 1, 2, and 3 had 1-hour residence times for the injected air before extraction began. The injected air had residence times of 5.9 and 14.7 hours for slug tests 4 and 5, respectively. The target volume of air for injection was

TABLE 4-8

FLOW RATES AND VOLUMES OF INJECTED AIR AND EXTRACTED GAS FOR THE SLUG TESTS

Test	Injected Air		Extracted Gas	
	Average Flow Rate[a] scfm (std m^3/min)	Volume[b] std ft^3 (std m^3)	Average Flow Rate[a] scfm (std m^3/min)	Volume[b] std ft^3 (std m^3)
Slug 1 (1.0 hour)[c]	90 (2.6)	2,700 (77)	60 (1.7)	1,000 (28)
Slug 2 (1.0 hour)	93 (2.6)	2,700 (76)	43 (1.2)	1,100 (32)
Slug 3 (1.0 hour)	87 (2.5)	2,600 (74)	44 (1.3)	1,200 (34)
Slug 4 (5.9 hours)	88 (2.5)	2,500 (72)		
extraction for time zero sampling			44(1.2)	53 (1.5)
second extraction			42 (1.2)	1,000 (28)
total volume extracted				1,053 (29.5)
Slug 5 (14.7 hours)	89 (2.5)	2,500 (70)		
extraction for time zero sampling			44 (1.2)	26 (0.74)
second extraction			36 (1.0)	1,000 (31)
total volume extracted				1,026 (31.7)

[a]Calculated from data in Appendix O.
[b]From data in Appendix O.
[c]Residence time of injected air before extraction began.

2,500 cubic feet (see Section 2.2.3). The flow rates for injecting the air were set so that the 2,500 cubic feet of air was injected in approximately 30 minutes. As can be seen by comparing the volumes of injected air for each slug test, the target volume of 2,500 cubic feet was delivered reproducibly (see Table 4-8), given all of the variables to be considered during the transfer. The goal of the extraction step in each slug tests was to withdraw a portion of the landfill gas near the extraction well at a slow enough rate to allow for the scheduled sampling and monitoring activities (see Table 3-2). The air not withdrawn during the slug test was displaced by the introduction of the next slug of air for testing. Comparison of the average flow rates and volumes of extracted gas for each slug test shows that sampling and monitoring activities required approximately the same amount of time for each test.

4.3.1.2 Vacuum and Pressure Data. Vacuum and pressure data were collected at the process trailer and from beneath the landfill cap at EX-1, PV-2, EP-11, and EP-12. As stated earlier, the process trailer data were used to calculate flow rate and volume data. The data presented in this section relate to the vacuum measured in the landfill during the course of these tests as ambient air was injected and gas was extracted from the landfill. All vacuum and pressure data collected or calculated are given in Appendix O.

Figure 4-35 shows the vacua measured at the extraction well during the slug testing period. The text at the top of the graph indicates the duration of each slug test (also included on Figures 4-36 through 4-40). Each negative vacuum (actually a pressure) indicates the injection of ambient air into the landfill. Each positive vacuum (a true vacuum) indicates the extraction of gas from the landfill. Although each slug test was separated by a certain amount of time, the vacua are plotted all together to show the overall response of the landfill to these tests. Figures 4-36 and 4-37 serve to illustrate this point more clearly. Figure 4-36 shows all of the vacua measured in the landfill during the tests; Figure 4-37 shows the vacua measured at the probes on the landfill without the extraction well vacua. The changes in vacua measured at the probes were a result of the vacua created at the extraction well. Figure 4-36 shows that these probe vacua changes were slight in comparison to those shown at the extraction well. Figure 4-37 shows these probe vacua on a different scale and allows a better look at the changes. In general, the vacua at all three probes are about the same and seem to respond to the injection and extraction of air at the extraction well. Comparison of these vacua with the slug tests denoted at the top of

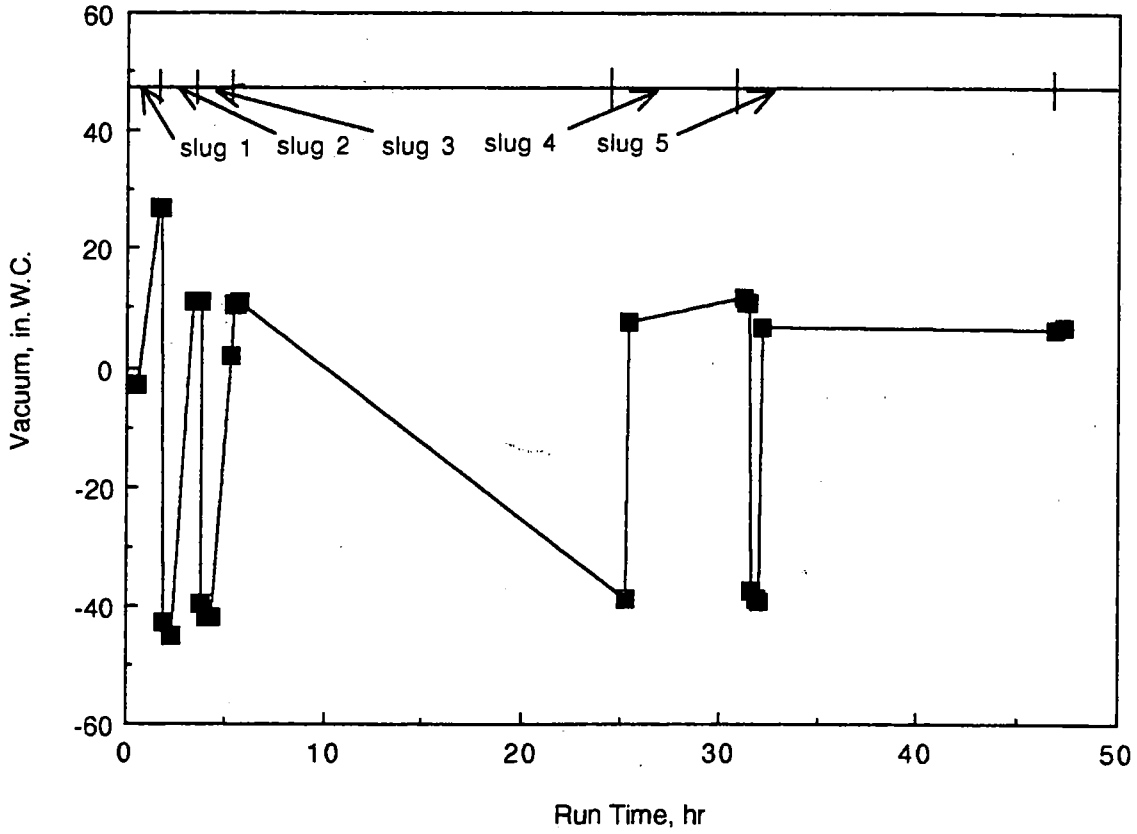


Figure 4-35. Slug Tests: Vacua at Extraction Well EX-1 versus Run Time

Note: Negative vacua are pressures generated during injection phase.

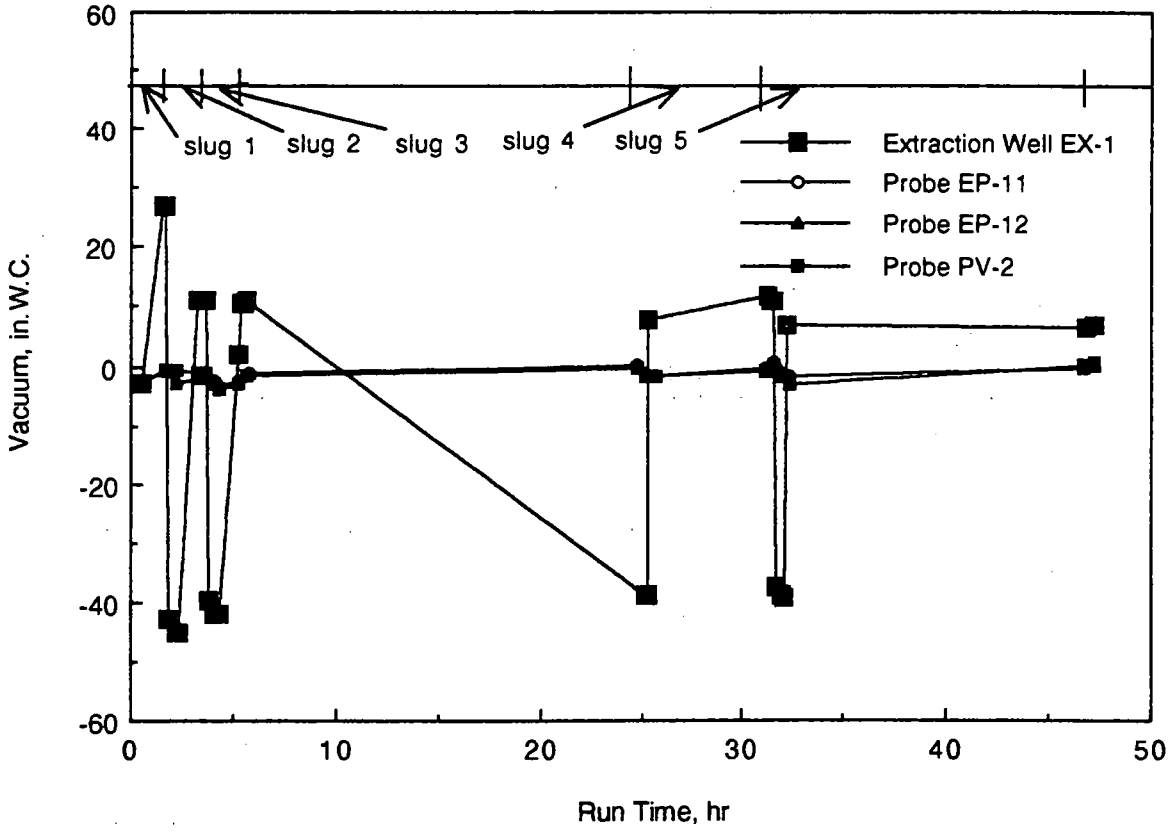


Figure 4-36. Slug Tests: Vacua in Landfill versus Run Time

Note: Negative vacua are pressures generated during injection phase.

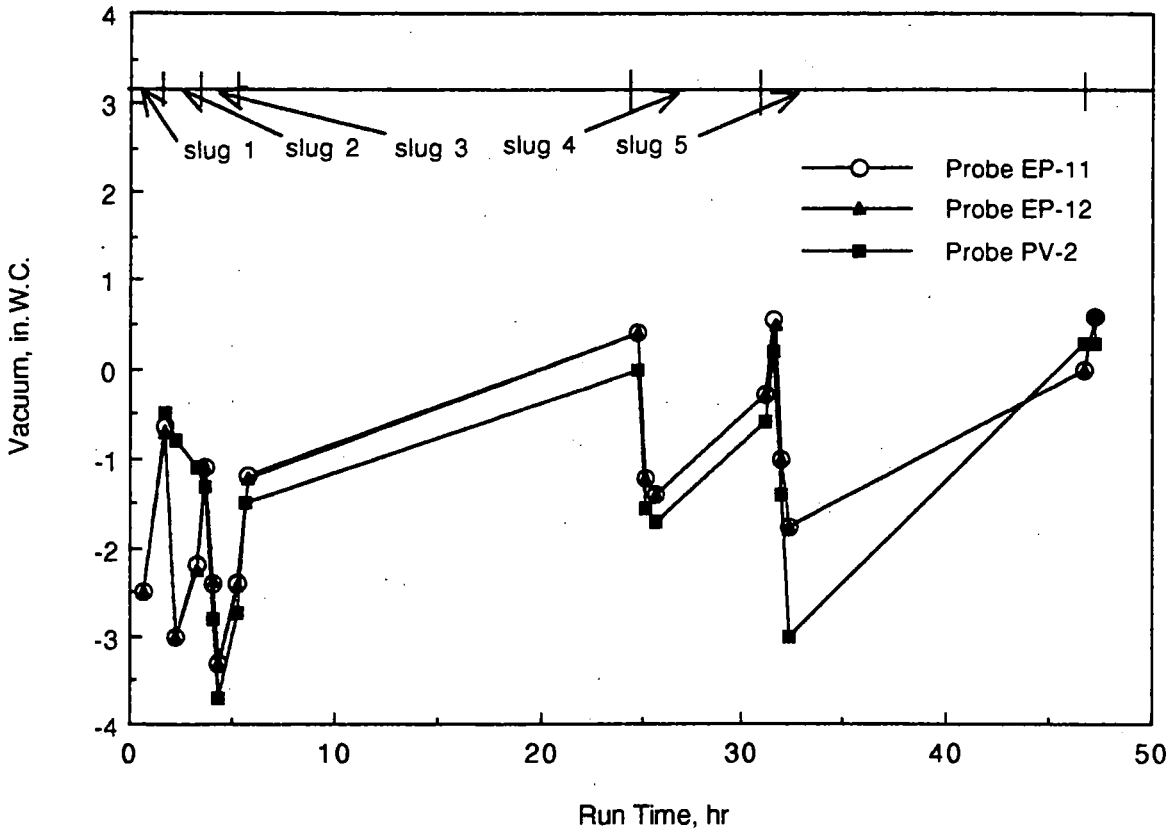


Figure 4-37. Slug Tests: Vacua at Probes in Landfill versus Run Time

Note: Negative vacua are pressures generated during injection phase.

the graph and with the vacua measured at the extraction well show that there was some lag time in the response of the probe vacua to the injection and extraction events.

4.3.1.3 Temperature Data. Temperature data were collected at the pitot tube at the process trailer and from beneath the landfill cap at EX-1, PV-2, EP-11, and EP-12. All temperature data are given in Appendix O for the slug tests. Figure 4-38 shows the temperatures measured at the extraction well for each slug test. The graphical notation is the same as discussed for Figure 4-35. In general, the temperatures decreased as the tests were performed. This could be a reflection of the fact that approximately 2,500 cubic feet of ambient air was injected in each slug test and the ambient air was colder than the air inside the landfill. On the first day of slug testing, the National Weather Service reported an average temperature of 5.6°C (42°F), and the next two days of slug testing were even cooler (snow was recorded on the final day of testing). Figure 4-39 shows all the temperature data measured beneath the landfill during the slug tests; Figure 4-40 shows only the temperature at the probes. The temperatures measured at the probes in the landfill varied much less than those at the extraction well. This behavior supports the conjecture regarding the introduction of the colder ambient air at the extraction well. The temperatures at probe EP-12 were consistently higher than those at probes EP-11 and PV-2. There was little difference between the temperatures measured at EP-11 and PV-2. Due to the questionable stability of the hand-held temperature readout device, the variations shown are not necessarily significant.

4.3.2 Soil-Gas Data

The soil-gas data collected during the slug tests consisted of field monitoring data measured with various hand-held gas monitoring instruments and of chemical-specific data from laboratory analysis of gas samples taken during the tests. Soil-gas data or samples for chemical specific were taken at the extraction well and carbon unit exhaust. No soil gas monitoring data from beneath the landfill cap were taken at any of the probes. All discussion of results of carbon exhaust monitoring/sampling is presented in Section 4.5.1. A discussion of the sample analyses is given in Section 3.2.2.2.

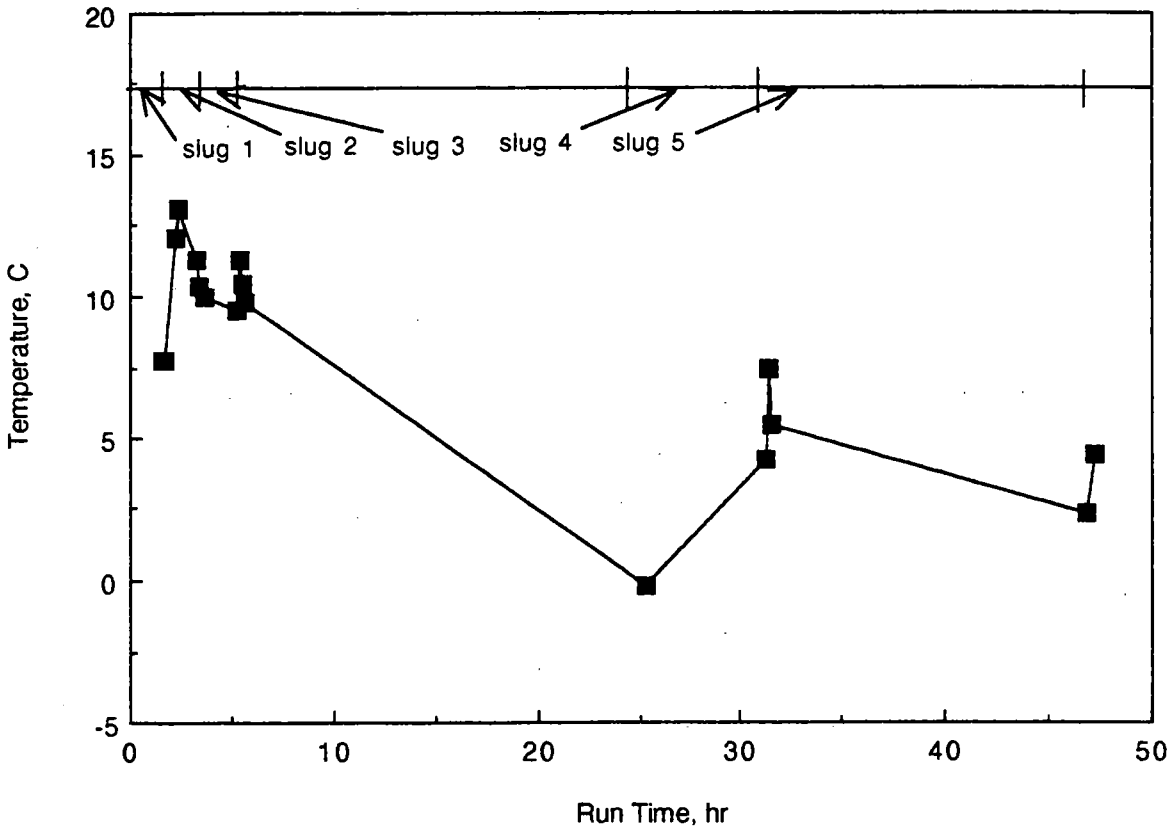


Figure 4-38. Slug Tests: Temperatures at Extraction Well EX-1 versus Run Time

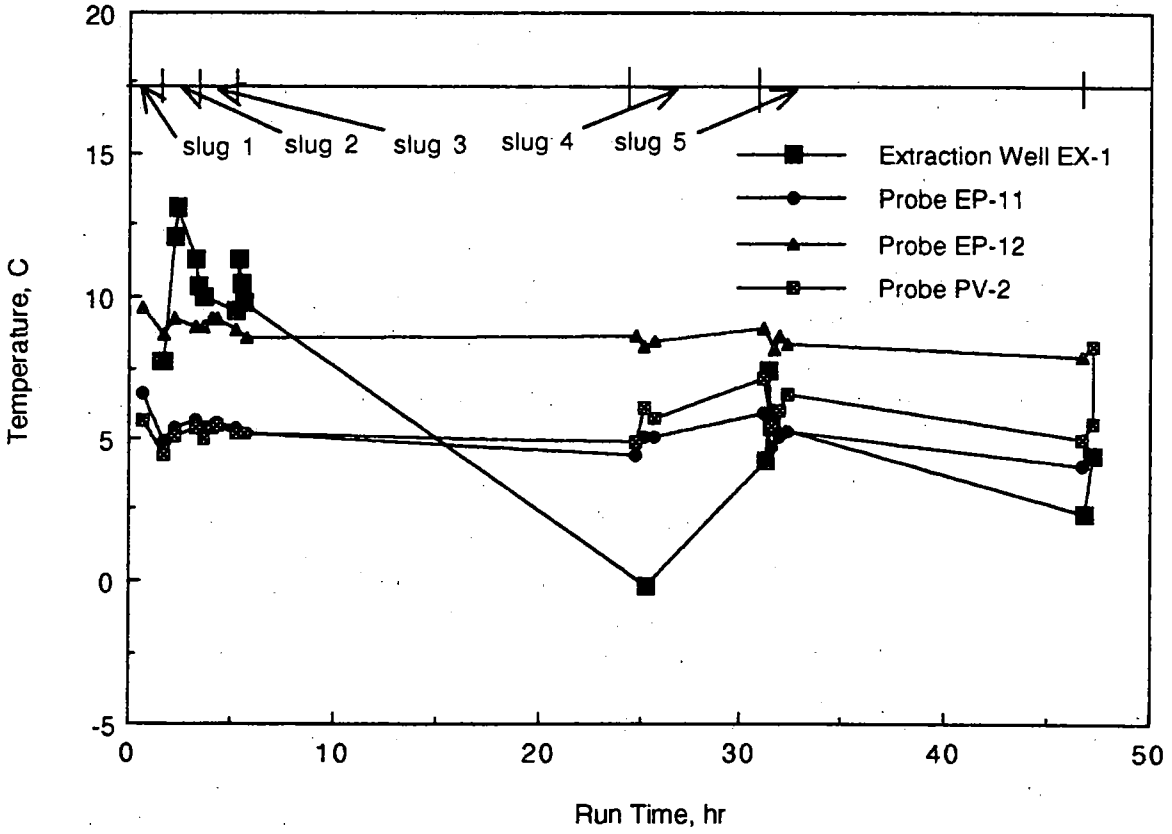


Figure 4-39. Slug Tests: Temperatures in Landfill versus Run Time

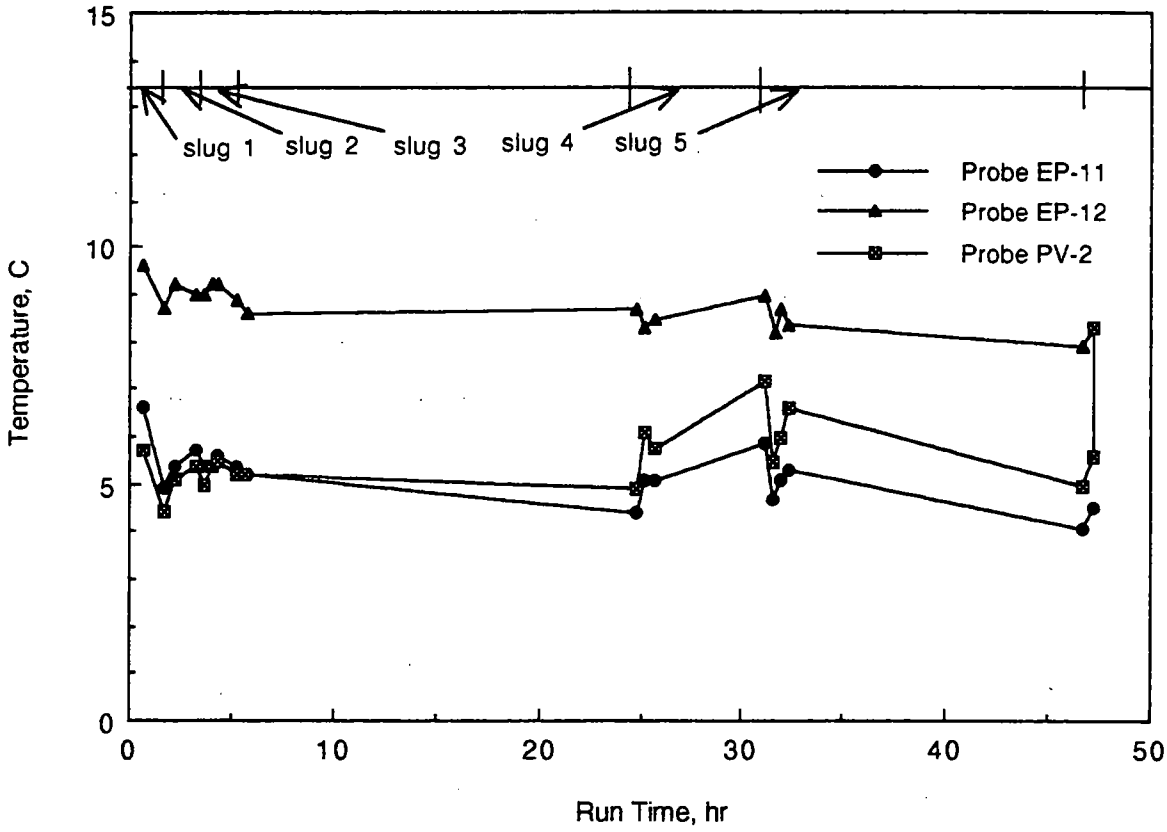


Figure 4-40. Slug Tests: Temperatures at Probes in Landfill versus Run Time

4.3.2.1 Field Monitoring Data. Field monitoring data were collected at the extraction well with hand-held monitoring instruments in the same manner as for the 75-hour test. The monitoring times and locations are given in Appendix O. Table 4-9 presents a summary of the field monitoring data for each slug test. Monitoring data are for the extracted gas only; no monitoring data were collected for the injected ambient air. The OVA readings exceeded the capacity of the instrument in all cases except for time zero in slug 4. The reason for this is unclear. The HNu readings showed higher VOC concentrations in the Slug 3 extracted gas than in the extracted gas for slug tests 4 and 5. The VOC concentrations were about the same for slug tests 4 and 5. The explosimeter data were variable among the individual slug tests. However, for each slug test, the percent LEL measured increased as more gas was extracted from the landfill. This increase followed the trend reported in the next section for the chemical-specific data.

4.3.2.2 Chemical Specific Data. Chemical specific data have been produced from analyses of gas samples collected in Tedlar® bags during the slug tests at the extraction well (EX-1) and at the carbon exhaust. All data pertaining to the activated carbon usage and performance are given in Section 4.5.1. Tedlar® bag samples were analyzed for methane (analysis according to method described in Appendix J) or the list of chemicals in Table 2-4 (analysis according to modified Method TO-14, see Section 2.4.2). Summary data sheets have been produced for each sample analyzed by modified Method TO-14. The raw data for all samples as supplied by the analytical laboratories are archived in-house (ECKENFELDER INC.) and are available upon request. The summary data sheets are provided in Appendix P. Each data sheet has the sample number, analysis date, and analytical laboratory listed at the top of the page. The body of the summary data sheets lists the chemicals on the analyte list, the concentrations reported, comments as appropriate, dilution factors, and total VOC concentrations. The last line in the table gives the sampling time. The results of the methane-specific analysis of all samples taken during Part 2 Testing are included as Appendix J.

Table 4-10 shows the concentration of the major organic compounds reported for gas samples collected at the extraction well for each slug test. Only the concentrations of total VOCs, vinyl chloride, 1,2-dichloroethene (total), trichloroethene, and methane are shown. The column showing elapsed time after air injection shows the sampling time relative to the end of the injection of the ambient air. The next

TABLE 4-9

FIELD MONITORING DATA COLLECTED AT THE EXTRACTION WELL IN EXTRACTED GAS DURING THE SLUG TESTS

Test	Elapsed Time After Air Injection[a] (hour)	Monitoring Instrument		
		OVA[b] (ppm)	HNu[c] (ppm)	Explosimeter (% LEL)
Slug 1 (1 hour)[d]	NA[e]	NA	NA	NA
Slug 2 (1 hour)	1.20	>1,000	NA	20
	1.42	>1,000	NA	29
Slug 3 (1 hour)	1.09	>1,000	300	15
	1.24	>1,000	300	19
Slug 4 (5.9 hours)	0.28	700	220	15
	5.92	>1,000	250	20
	6.08	>1,000	220	30
Slug 5 (14.7 hours)	14.75	>1,000	240	28

[a]Monitoring time measured from end of air injection.
[b]Organic Vapor Analyzer (flume ionization detector).
[c]Air monitoring instrument with photoionization detector.
[d]Residence time of injected air before extraction began.
[e]Data not available.

TABLE 4-10

RESULTS OF CHEMICAL SPECIFIC ANALYSES OF GAS EXTRACTED DURING SLUG TESTS

Test	Elapsed Time After Air Injection[b] (hour)	Volume of Extracted Gas[c] (% of injected gas)	Sample ID (Taken at Extraction Well)	Concentration[a] Total VOCs ppm, v/v	Vinyl chloride ppm, v/v	1,2-Dichloroethene (total) ppm, v/v	Trichloroethene ppm, v/v	Methane %, v/v
Slug 1 (1 hour)[d]	1.13	15	EX-28	3,900 (89)[e]	1,300	1,900	290	
	1.22	26	EX-29	512[f] (57)	110[f]	140[f]	41[f]	
Slug 2 (1 hour)	1.10	10	EX-30	2,600 (88)	750	1,300	250	
	1.12	12	MEX-07A					0.3
	1.25	24	EX-31	3,700 (87)	1,100	1,800	320	
	1.29	28	EX-32	4,100 (89)	1,300	2,000	350	
	1.32	31	MEX-08A					0.9
Slug 3 (1 hour)	1.12	12	EX-33	2,900 (86)	820	1,400	270	
	1.15	15	MEX-09A					0.2
	1.27	28	EX-34	4,100 (89)	1,400	1,900	330	
	1.29	29	MEX-10A					0.6
	1.32	32	MEX-11A					0.8
Slug 4 (5.9 hours)	0.05 (time zero)	2	EX-42	1,400 (85)	400	640	150	
	5.97	10	EX-35	4,800 (89)	1,700	2,200	370	
	6.0	13	MEX-12A					0.9
	6.12	25	EX-36	5,500 (89)	2,000	2,500	420	
	6.15	28	MEX-13A					2.0
Slug 5 (14.7 hours)	0.10 (time zero)	1	EX-37	1,000 (79)	170	490	130	
	14.82	15	MEX-14B	4,700 (88)	1,700	2,100	350	
	14.82	15	MEX-14A					1.0
	14.94	26	EX-39	5,000 (89)	1,900	2,200	350	
	14.97	28	EX-40	5,200 (90)	2,000	2,300	370	
	15.05	35	MEX-15A					2.0
	15.07	37	MEX-16A					2.0

[a]Concentrations taken from Summary Data Sheets in Appendix P and from report in Appendix J.
[b]Sampling time measured from the recorded end of air injection.
[c]Calculated by dividing the total volume injected for a given slug test by the total volume extracted at the sampling time.
[d]Residence time of injected air before extraction began is in parentheses after slug number.
[e]Numbers in parentheses in this column are the percent of total VOCs contributed by vinyl chloride, 1,2-dichloroethene, and trichloroethene.
[f]These data appear to be inconsistent with others and should not be considered in the evaluation.

column to the right shows the percent volume gas extracted relative to the total volume of air injected for each slug test. These numbers correspond to the predicted percent volumes given in Table 3-2 for the summary of the sampling and analysis plan for the slug tests. It was not physically possible to take all samples at exactly 10 percent and 25 percent volume extracted, but the data in Table 4-10 show that the schedule was met fairly well. Comparison of the concentrations of total VOCs, vinyl chloride, 1,2-dichloroethene (total), and trichloroethene shows that vinyl chloride and 1,2-dichloroethene (total) were in highest concentration (excluding methane), making up the major portion of the total VOCs. The concentrations were similar for slugs 1, 2, and 3. This is not unexpected since these three tests had the same injected air residence times. For slug tests 4 and 5, time zero samples were collected immediately after the air was injected by extracting gas for one minute. As would be anticipated these time zero concentrations are markedly lower than the concentrations of extracted gas after residence times of about six and 15 hours. Comparison of the results for slug tests 4 and 5 shows very little difference in concentrations; the concentrations are somewhat higher than those reported for slug tests 1, 2, and 3. In all sample results shown in Table 4-10 except for sample EX-29 results, the concentrations of vinyl chloride, 1,2-dichloroethene (total), and trichloroethene made up 79 to 90 percent of the total VOCs reported as present above the LOQ by the Lord Corporation Laboratory.

4.3.3 Discussion of Results

The results of the slug tests indicated desorption/diffusion of VOCs in the landfill did occur to measurable levels. The test was performed after the passive vent test in every effort to use as "clean" an area of the site as possible. It was hoped that as much as possible of the localized interstitial (i.e., easily removed) VOCs had been stripped prior to start up.

The chemical specific data present generally reproducible upward trends in concentration in the extracted slug with increasing contact time. An approximate diffusion constant can be determined from these data (see Section 5.0).

Table 4-11 provides a comparison of the methane concentration measured by the explosimeter during this test and the corresponding chemical-specific analysis concentration. The percent LEL values provided by the explosimeter were converted

TABLE 4-11

COMPARISON OF METHANE CONCENTRATION MEASURED BY EXPLOSIMETER AND CHEMICAL SPECIFIC ANALYSIS OF SOIL GAS SAMPLES DURING SLUG TESTS

Test	Elapsed Time After Air Injection[a] (hour)	Methane Concentration		
		Measured by Explosimeter		From CSA
		% LEL	ppm[b] (v/v)	ppm (v/v)
Slug 1 (1 hour)[c]		NA[d]	NA	NA
Slug 2 (1 hour)	1.12			0.3
	1.20	20	1.1	
	1.42	29	1.5	
Slug 3 (1 hour)	1.09	15	0.8	
	1.15			0.2
	1.24	19	1.0	
	1.29			0.6
	1.32			0.8
Slug 4 (5.9 hours)	0.28	15	0.8	
	5.92	20	1.1	
	6.00			0.9
	6.08	30	1.6	
	6.15			2.0
Slug 5 (14.7 hours)	14.75	28	1.5	
	14.82			1.0
	15.05			2.0
	15.07			2.0

[a]Sampling time measured from the recorded end of air injection.
[b]Calculated from explosimeter reading by % LEL x 5.3 ppm (v/v) where 5.3 ppm (v/v) is the LEL for methane.
[c]Residence time of injected air before extraction began.
[d]Data not available.

to ppm, v/v by multiplying the LEL for methane, 5.3 ppm, by the monitored percentage (in fraction format). The values agree well to one or two significant figures. This, as an independent check, helps support the quality of the laboratory data or conversely, the performance of the monitoring unit.

4.4 TOE AND CREST TEST RESULTS

This section contains the results of tests performed at the toe and crest wells during Part 1 and Part 2 Testing. A summary of the data collected during Part 1 testing on November 13 and 14, 1991 was presented in an interim report (see Appendix B). The tests performed during Part 2 Testing were made on March 30 and 31, 1992. As with the discussion of the previous tests, the process data are presented first, followed by the chemical data. A discussion of the test results is given in section 4.4.3.

4.4.1 Process Data

Process data collected using the portable ISVS unit (see Section 2.3 for a description of the unit) consisted of extracted gas flow rate and temperature, wellhead vacuum, pump vacuum. Barometric pressure was also measured with the barometer which was kept at the process trailer. Table 4-12 presents a summary of the data collected during the Part 1 testing (this table is similar to Table 3 in the interim report, Appendix B). The process data from Part 2 testing are given in Appendix Q. Appendix Q also contains the chemical monitoring data for these tests; these data will be discussed in the next section.

During the Part 1 testing at the toe and crest wells, soil-gas was extracted from each well on days one and two for about 20 to 30 minutes at the maximum achievable flow rate for each well. Table 4-12 shows that gas flow was achieved in all wells except toe well 2 (TC-2). A value of >150 in.W.C. for the vacuum at the wellhead indicates that the vacuum in the well exceeded the capacity of the gauges on the portable ISVS unit. Once the capacity was exceeded, the test at that particular well was terminated. The flow rates in Table 4-12 have not been corrected to scfm because the data needed to make this correction were not available for these tests. Table 4-13 presents a summary of the extracted gas flow rates and associated vacua for the toe and crest wells during the Part 2 test period. The screens at wells TC-2

TABLE 4-12

SUMMARY OF FLOW AND VACUUM DATA FROM TOE AND CREST WELLS TAKEN DURING PART 1 TESTING[a]

Well	Day 1					Day 2		
	Flow, cfm		Vacuum, in.W.C.		Elapsed Time, min	Average Flow, cfm	Average Vacuum, in.W.C.	Elapsed Time, min
	Initial	Final	Initial	Final				
TOE AREA								
TC-1	8	7.8	40	39	20	7.7	37	28
TC-2	4.5	4.5	>150	>150	26	4.4	>150	20
TC-3	8.1	8.2	13	14	34	8.1	14	23
TC-4	8.3	8.1	17	17	27	8.0	16	38
TC-5	8.1	8.1	22	23	22	7.9	22	53
CREST AREA								
TC-6	8.3	8.3	8	8	20	8.2	7.3	21
TC-7	8.3	8.2	10	10	14	8.2	10	50
TC-8	8.2	8.2	15	15	18	8.2	14	13

[a]November 13 and 14, 1991.

TABLE 4-13

FLOW RATE AND VACUUM DATA COLLECTED AT TOE AND CREST WELLS DURING PART 2 TESTING[a]

Well	Measured Flow Rate (cfm)	Calculated Flow Rate (scfm)	Vacuum[b] (in.W.C.)	Elapsed Time (min)
TOE AREA				
TC-1	0	0	>150	2
TC-2	0	0	>150	1
TC-3	3	1.3	4	3
	5	2.8	21	4
	7.5	5.7	53	7
TC-4	2.9	1.3	92	7
	4.2	0	>150	0
TC-5	3	1.3	70	4
	5	0	>150	0
CREST AREA				
TC-6	3.1	1.4	1.0	3
	5.0	2.9	4.5	5
	7.6	5.9	18	4
TC-7	3	1.3	2.0	4
	5	2.9	7.3	8
	7.6	5.9	27.5	47
TC-8	3.1	1.39	2.5	4
	5.0	2.89	10	9
	7.7	5.96	33	10

[a]March 30 and 31, 1992.
[b]Measured at inlet to portable ISVS unit.

and TC-3 were apparently clogged and no flows were developed. Wells TC-4 and TC-5 could be developed only at very low flow rates. When the flow rates were increased at these wells, the vacua exceeded the capacity of the portable unit and testing was terminated. The tests at Wells TC-3, TC-6, TC-7, and TC-8 were more successful. The wellhead vacua were measured at the different flow rates for each well. Figure 4-41 shows a plot of vacuum versus flow rate for these four wells. The curves are fitted to the experimental data with a second degree polynomial equation (a quadratic fit).

4.4.2 Soil Gas Data

Soil gas data were collected during both test periods at the toe and crest wells. During the Part 1 testing, soil gas samples were collected in Tedlar® bags at each well on each test day. Monitoring data were also recorded from OVA readings and Draeger tube measurements of the exhaust from the portable ISVS unit. Vinyl chloride and methane were measured with the colorimetric tubes. During Part 2 testing, monitoring data were collected with the OVA at each well while the flow tests were being conducted. The results of the chemical specific analyses by the Lord Corporation Laboratory are presented as Appendix R. These data are presented as received at ECKENFELDER INC. from Lord Corporation; no summary data sheets were made. The OVA data for the Part 2 testing on March 30 and 31, 1992 is included in Appendix Q.

Table 4-14 is a qualitative assessment of the VOCs which were detected in the soil gas samples collected from the toe and crest wells during the Part 1 testing. A similar table was presented as Table 1 in the interim report in Appendix B. After additional review of the data, some changes have been made to produce Table 4-14. Table 4-15 gives a qualitative summary of the chemical data from the chemical specific analyses and the OVA monitoring data for all wells during both test periods. The total VOCs reported were calculated by adding the concentrations of all compounds reported for a given sample. (Sample numbers in Appendix R, which provides the chemical specific analyses, are coded as follows: TC-1-1 was taken at well TC-1 and was the first sample, corresponding to Day 1, start. Samples ending in a -3 and -5 were taken on Day 1, finish and Day 2, respectively. A summary table for tetrachloroethene, the most prevalent VOC, is provided in Appendix R as is a table for vinyl chloride and methane. The concentration of tetrachloroethene

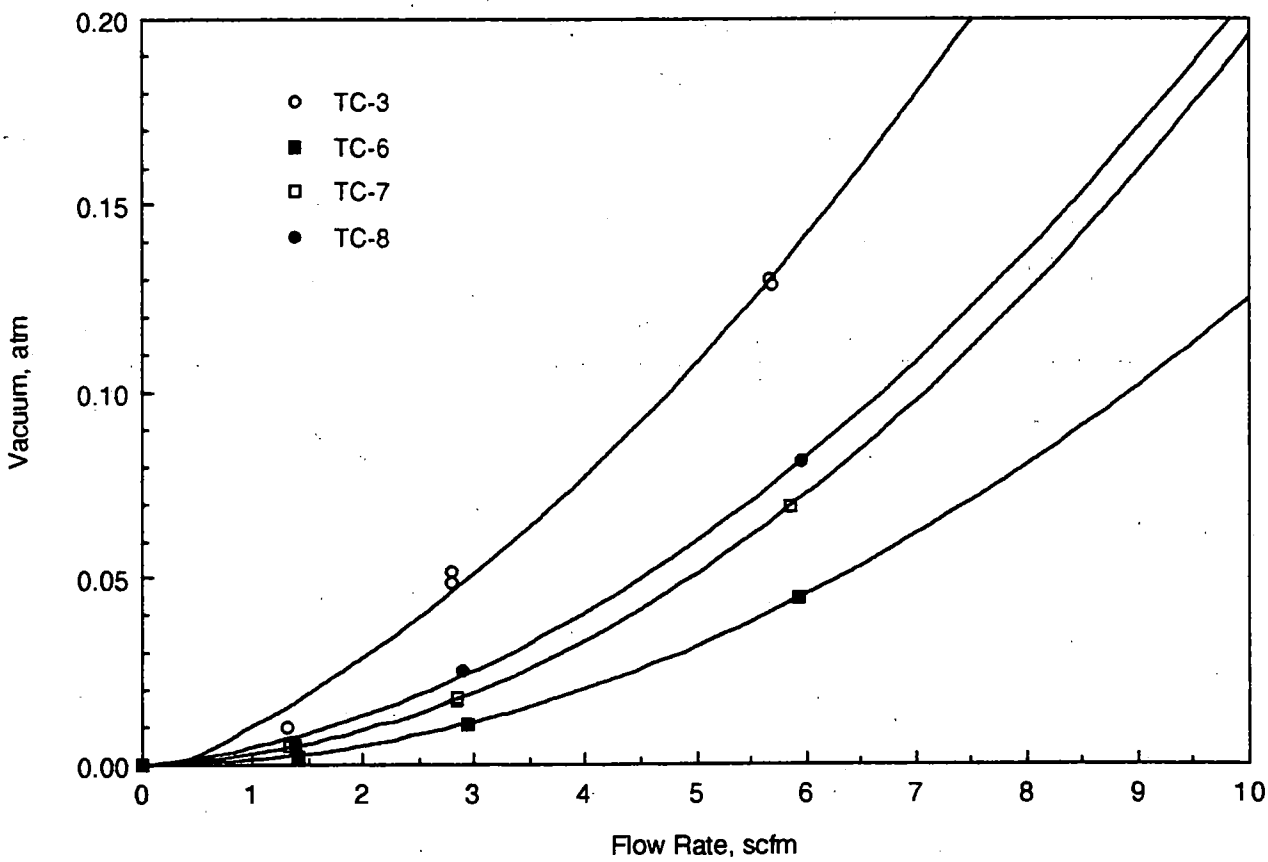


Figure 4-41. Toe and Crest Tests: Vacuum versus Flow Rate for Wells TC-3, TC-6, TC-7, and TC-8

TABLE 4-14

QUALITATIVE ASSESSMENT OF THE PRESENCE OF VOLATILE ORGANIC COMPOUNDS AT THE TOE AND CREST WELLS FROM CHEMICAL SPECIFIC ANALYSES OF SAMPLES COLLECTED DURING PART 1 TESTING

Volatile Organic Compounds	Toe Area Well					Crest Area Well		
	1	2	3	4	5	6	7	8
Vinyl chloride	X[a]	X	X	X	X			X
Acetone			X					
Methylene chloride		X	X		X			
trans-1,2-Dichloroethene	X		X					
1,2-Dichloroethane		X						
cis-1,2-Dichloroethene	X	X	X	X				
Benzene	X							
Trichloroethene	X	X	X	X	X	X	X	
Methyl isobutyl ketone (4-Methyl-2-pentanone)	X	X	X	X	X			
4-Methyl-2-pentanol	X	X	X					
Toluene	X	X	X	X	X	X		X
Tetrachloroethene	X	X	X	X	X	X	X	X
Chlorobenzene			X					
1,3-Dimethylbenzene[b]	X	X	X	X	X	X		X
Cyclohexanone			X					
1,2-Dimethylbenzene[c]	X	X	X	X	X			X

[a]An "X" indicates that the compound was detected in one or more samples.
[b]Meta xylene.
[c]Ortho xylene.

Also, the following volatile organic compounds were analyzed for but not detected in the samples: chloromethane, trichlorofluoromethane, 1,1-dichloroethane, tetrahydrofuran, and 1,1,2,2-tetrachloroethane.

TABLE 4-15

SUMMARY OF THE TOTAL VOC DATA FOR TOE AND CREST WELLS

VOC CONCENTRATION FROM CHEMICAL SPECIFIC ANALYSIS (FROM OVA), ppm (v/v)

Well	Day 1, (11/13/92) Start	Day 1, (11/13/92) Finish	Day 2 (11/14/92)	3/30/92 or 3/31/92
TOE AREA				
TC-1	6.7 (22)	89 (20)	18 (13)	NA
TC-2	8.1 (4)	NA (2.8)	4.3 (NS)	NA
TC-3	3.1 (8.5)	2.8 (32)[a] 10.5 (33)	4.7 (22)	(2-14)
TC-4	7.5 (100)	2.1(160)	12 (120)	(1-3)
TC-5	2.5 (270)	6.8 (430)	9 (410)	(1.8)
CREST AREA				
TC-6	4.9 (200)[a] 10.5 (200)	6.6 (180)	15 (170)	(110-150)
TC-7	13 (780)	17 (600)	12 (350)	(32-320)
TC-8	1.3 (>1,000)[b]	1.3 (>1,000)	67(>1,000)	(>1,000)

NA - No data available.
NS - Not sampled.

[a]Duplicate analyses.
[b]Draeger tubes did not indicate methane.

governed the dilution factors. Methane was not detected during the monitoring of the soil gas.)

4.4.3 Discussion of Results

The review of the toe and crest data generated in November 1991 indicates the presence of VOCs in the soil but at seemingly lower concentrations than monitored under the landfill cap. A similar menu of constituents compared to those detected under the cap was identified. There was little to no methane and vinyl chloride, however. The relatively high (and variable) water table in the toe area will have to be accommodated in the final design.

The non-Darcian behavior of the flow rate and vacuum relationship was exhibited in the toe and crest wells where water levels or screen clogging did not preclude measurements. These data (see Figure 4-41 and Table 4-16 for the curves, fit, and associated equations) may permit the use of models at the toe and crest areas during full scale design in conjunction with previously acquired soil concentrations (see Clarke, et al., 1992).

4.5 OTHER RESULTS

Data pertaining to the performance of the activated carbon adsorption unit are presented in this section as well as data on the condensate that were collected during Part 2 of the treatability testing.

4.5.1 Carbon Unit Performance Data

Performance data that were collected on the activated carbon unit included both process data and chemical specific data related to the removal of VOCs from the gas stream.

4.5.1.1. Process Data. Process data that were measured during both the 75-hour test and passive vent test include total exhaust flow, differential pressure, and gas temperatures. In addition, the relative humidity of the gas entering the activated carbon unit was calculated. As previously discussed, the total gas flow rate through the carbon was maintained between about 50 scfm and 95 scfm during the 75-hour

TABLE 4-16

CONSTANTS GENERATED BY A LEAST SQUARES FIT OF VACUUM AND FLOW DATA AT TOE AND CREST WELLS TO AN EQUATION DESCRIBING NON-DARCIAN BEHAVIOR

Well	A_1	A_2	r^2
TC-3	0.00974	0.00233	0.9923
TC-6	-0.0000687	0.0126	0.9998
TC-7	0.00105	0.00182	0.9964
TC-8	0.00307	0.00177	0.9986

[a]Equation used was $V_w = A_1Q + A_2Q^2$ where

- V_w is wellhead vacuum in atmosphere (atm)
- Q is the gas flowrate in standard cubic feet per minute (scfm)
- A_1 is the viscous resistance coefficient, relating to viscous resistance and several system-specific parameters
- A_2 is the inertial resistance coefficient, relating to inertial resistance and several system-specific parameters
- r^2 indicates goodness of fit. 1.0000 is a perfect fit

test (refer to Figure 4-2) and was maintained between about 80 and 95 scfm during the passive vent test (refer to Figure 4-23). The differential pressure during the 75-hour test ranged from 1.3 to 2.1 in.W.C. (refer to Figure 4-10) and ranged from 1.9 to 2.3 in.W.C. during the passive vent test (refer to Figure 4-29). Both the carbon exhaust flow rate and carbon unit differential pressure during the treatability tests were maintained at less than 10 percent of the rated values for those process parameters. The gas temperature entering the carbon unit (blower discharge temperature on Figure 4-13) was maintained between 20-31°C (68 and 88°F) during the 75-hour test and was maintained between 26-31°C (79 and 88°F) during the passive vent test (refer to Figure 4-32). As previously discussed, the temperature of the carbon exhaust was higher than the inlet temperature due to the heat of adsorption of the VOCs onto the carbon. The carbon exhaust temperature was as high as 37 or 38°C (99 or 100°F) during both the 75-hour test and passive vent test.

The relative humidity (RH) of the gas at the inlet to the carbon unit was calculated assuming that the water vapor at the pitot tube location was at its saturation vapor pressure. Relative humidity at the carbon unit inlet was calculated after correcting for the gas pressure and temperature increases across the blower. According to the carbon unit manufacturer, if the RH of the gas entering the carbon unit exceeds 50 percent RH, then the water vapor can compete more successfully with the VOCs for adsorption sites on the carbon. This is especially true as the RH approaches 100 percent. The calculated RH values for the 75-hour test and passive vent test are shown graphically in Figures 4-42 and 4-43 respectively.

The RH ranged typically between 25 percent and 45 percent during both tests. Only for a brief period during the 75-hour test at about 5 hours run time did the RH exceed 50 percent (refer to Figure 4-42) where the RH reached about 58 percent). In summary, the process parameters, including gas flow, differential pressure, temperature, and RH were maintained well within the acceptable range for the activated carbon unit.

4.5.1.2 Chemical Data. The chemical data collected at the carbon exhaust consist of monitoring data and chemical specific data. The monitoring data were collected using the hand-held monitoring instruments by measuring the exhaust adjacent to the exhaust stack or by measuring the exhaust from the diaphragm gas sampling

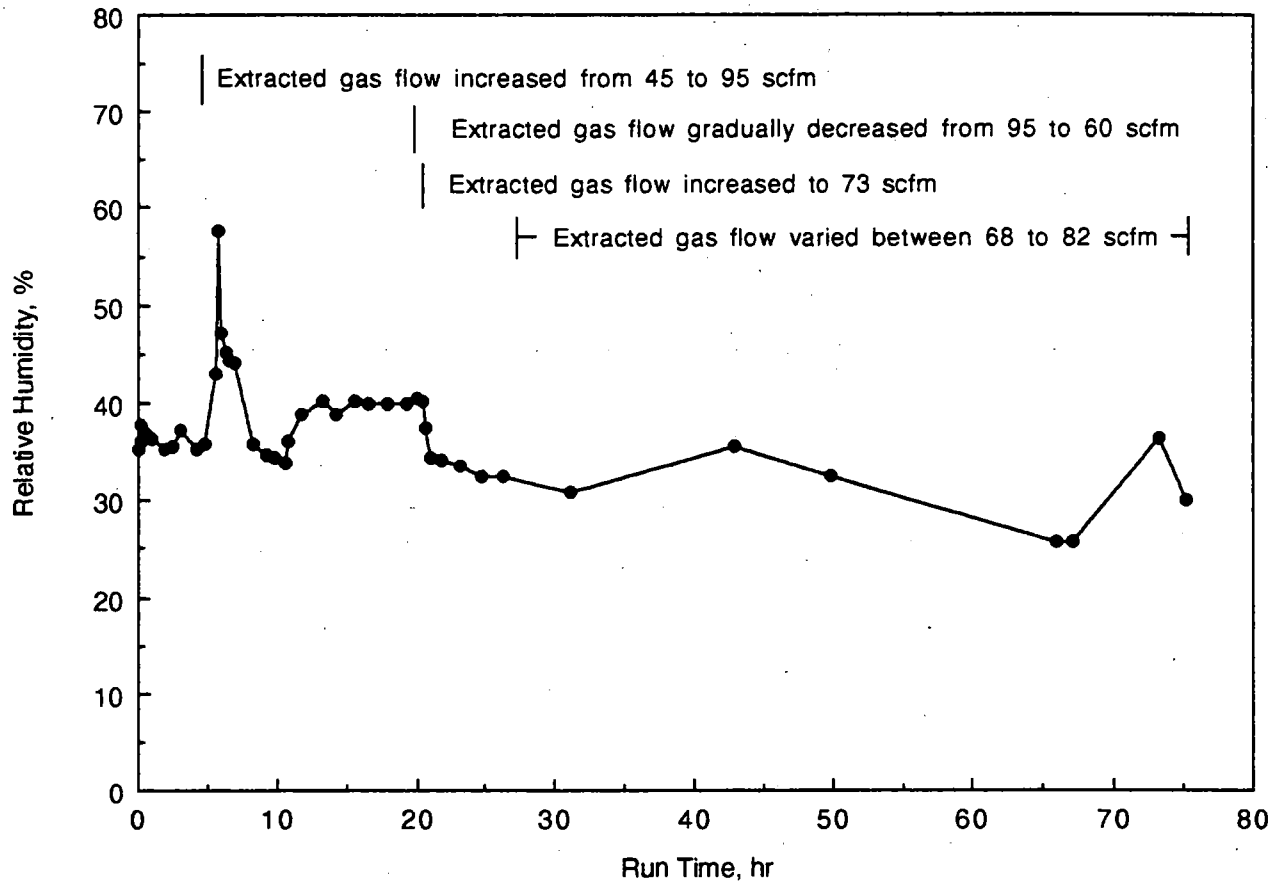


Figure 4-42. 75-Hour Test: Relative Humidity of Gas to Carbon Unit versus Run Time

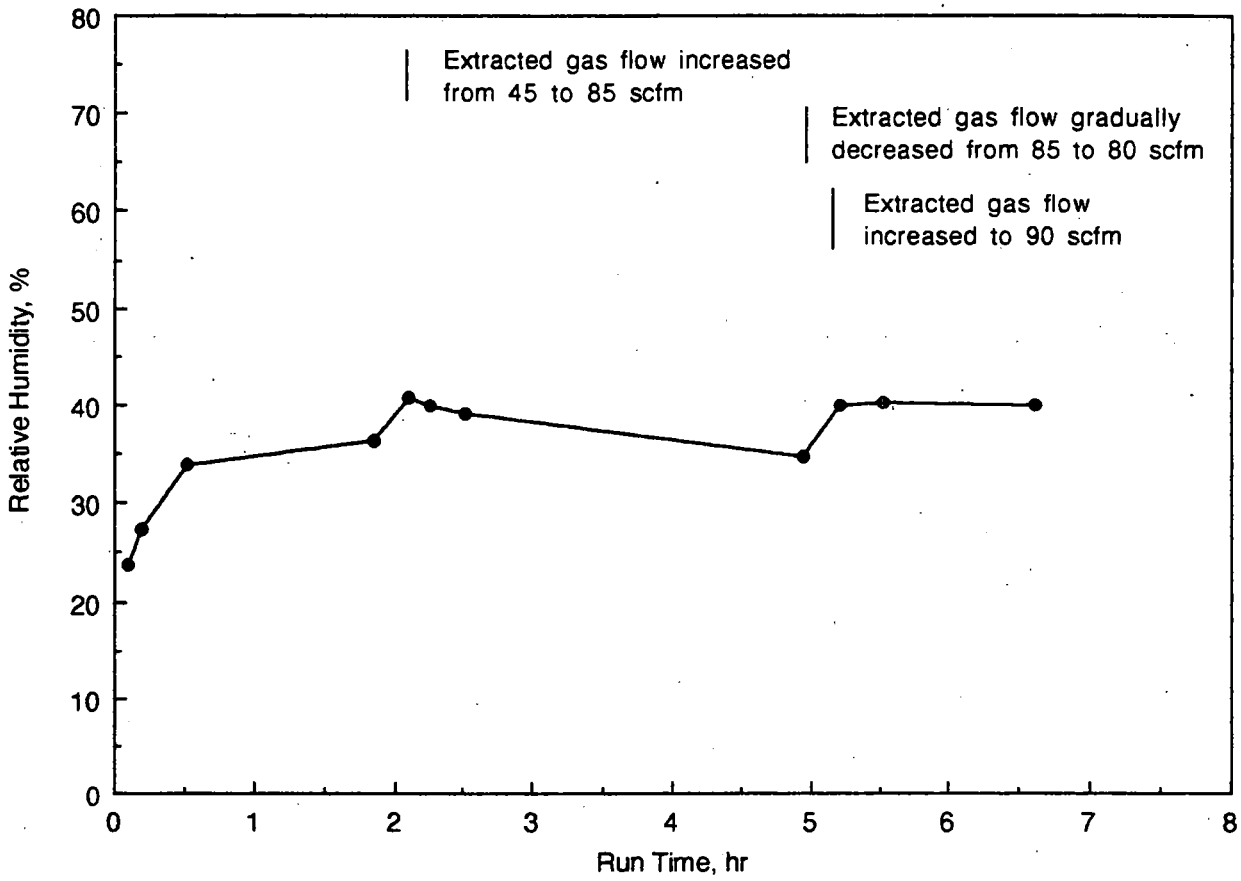


Figure 4-43. Passive Vent Test: Relative Humidity of Gas to Carbon Unit versus Run Time

pump which was used to collect carbon exhaust gas samples. All gas samples taken for chemical specific analysis were taken using the diaphragm gas sampling pump by the same procedure as all other samples taken during the testing.

Table 4-17 presents the chemical monitoring data collected at the carbon exhaust during the 75-hour ISVS test and the 8-hour passive vent test. These data may also be found in Appendix H (75-hour test field monitoring data) and Appendix M (8-hour passive vent test field monitoring data). Because of the presence of methane, both the OVA and explosimeter readings were out of range of the respective instruments for the 75-hour test; the OVA readings were out of range during the passive vent test, but one reading of 52 percent LEL was recorded using the explosimeter. High methane concentrations caused the readings on the OVA and explosimeter to be off scale. The HNu is "blind" to methane and thus readings were recorded. The HNu data should be reviewed with caution, however, because several factors contribute to possible errors in the recorded data. As was discussed in Section 4.1.2.1, methane is a classic quencher of the HNu detector response. In fact, contrary to the reported chemical specific data trends, the HNu response increased at the extraction well during the 75-hour test as the methane concentration and VOC concentrations decreased. Thus the HNu monitoring data at the extraction well during the 75-hour test were not a reliable source of monitoring information. Another problem with the HNu data reported in Table 4-17 is that two different HNu instruments were used. The HNu supplied by ECKENFELDER INC. was used for the first two monitoring/sampling events listed under the 75-hour test. Because of some difficulties with the battery charger on the ECKENFELDER INC. HNu, a second HNu, supplied by Lord Corporation, was used for the remainder of the monitoring/sampling events in the 75-hour and passive vent tests. As indicted in the footnote to Table 4-17, the HNu supplied by Lord Corporation was reading concentration of VOCs as being approximately twice the actual value. This was determined by calibration check procedures, i.e., using a calibration gas of known concentration. The reason for these high readings is not known. The question ability of the readings from the HNu supplied by Lord Corporation combined with the problems in HNu detector response when methane concentrations were high, lead to some suspicion of the validity of the data given in Table 4-17.

Because the HNu data were the only real-time data available at the carbon exhaust, these data were used as a guide for when to discontinue use of the carbon unit. Use

TABLE 4-17

CHEMICAL MONITORING DATA COLLECTED AT THE CARBON EXHAUST DURING THE 75-HOUR ISVS TEST AND THE 8-HOUR PASSIVE VENT TEST

Sampling Time[a] (hour)	Monitoring Instrument		
	OVA[b] ppm (v/v)	HNu ppm (v/v)	Explosimeter[c] % LEL
75-hour ISVS Test			
1.82	>1,000	15.4[d]	>100
10.78	NA[e]	5[d]	>100
19.80	>1,000	27[f]	>100
73.50	>1,000	200[f]	>100
8-hour Passive Vent Test			
5.27	>1,000	70 - 600[f]	NA[e]
7.27	>1,000	640[f,g]	52

[a]Time relative to start of test.
[b]Readings >1,000 ppm indicate that the gas concentration exceeded the maximum concentration that the OVA could measure.
[c]Readings >100 percent LEL indicate that the gas concentration exceeded the maximum concentration that the explosimeter could measure.
[d]Data collected with ECKENFELDER INC. HNu.
[e]Data not available.
[f]Data collected with Lord Corporation HNu unit (calibration check indicated that instrument was reading concentrations as being approximately twice their true value). The values reported in the table are the direct readouts, not adjusted for calibration.
[g]Test terminated; field indication that permit limit reached.

of the carbon unit was ended when the reading of 640 ppm (first reading above 200 ppm) was measured at 7.27 hours run time in the passive vent test. The emission permit required that after 200 ppm was reached in the carbon exhaust that testing should cease with a new carbon unit installed. The reading of 200 ppm recorded at the end of the 75-hour test was believed to be approximately 100 ppm based on calibration data, therefore, the carbon unit was left in place and used for the passive vent test. A final measurement of the carbon exhaust was made at the end of the extraction phase slug test. At this time, the HNu read 160 ppm; this HNu was the ECKENFELDER INC. unit which was reading true according to the calibration check made earlier that day.

The summary data sheets for all gas samples collected at the carbon exhaust are given as Appendix S. All QA/QC discussion is presented in Section 4.6. The compounds with concentrations above the LOQ in samples analyzed by Lord Corporation have been used to calculate an estimate of the total masses of these compounds in the exhaust from the carbon unit during the 75-hour test and the passive vent test. Process data such as gas flow rate and volume through the carbon unit and carbon unit temperature were also used for the calculation. The calculated masses of compounds in the carbon exhaust during the 75-hour test are given in Table 4-18. The total mass of VOCs exhausted during the passive vent test was 17,000 g; vinyl chloride composed 99.9 percent of this total mass. Vinyl chloride was 99.8 percent of the total mass exhausted during the 75-hour test. If vinyl chloride were eliminated from the assessment of carbon performance, an average percent retention of 99.6 percent can be determined. This percent retention value is still impacted by the fact that some vinyl chloride is sorbed to the carbon. These calculated values for mass and percent retention were confirmed by a second, independent calculation.

4.5.2 Condensate Collection Data

The second waste stream generated by operation of the mobile ISVS unit was a condensate stream (the other waste stream was the extracted gas which was treated using the activated carbon unit). The condensate was generated in the extraction pipe lying between the extraction well and the process trailer because the ambient temperature was typically lower than the temperature of the extracted gas. The condensate collected in the lowest-lying portion of the extraction pipe (the pipe ran

TABLE 4-18

SUMMARY OF MASSES OF COMPOUNDS ENTERING AND LEAVING ACTIVATED CARBON UNIT DURING 75-HOUR ISVS TEST

Compound	Calculated Mass		
	Entering Carbon[a] (g)	Leaving Carbon[b] (g)	Percent Retention[c] (%)
Vinyl chloride	120,000	94,000	25
Acetone	5.6	0	100
2-Propanol	6.6	0	100
1,2-Dichloroethene (total)	110,000	7.7	(~100) 99.999
1,1-Dichloroethane	230	0	100
2-Butanone	300	0	100
2-Butanol	19	0	100
Chloroform	37	0	100
Tetrahydrofuran	430	0	100
Benzene	200	0	100
Trichloroethene	15,000	61	99.6
4-Methyl-2-pentanone	5,600	11	99.8
Toluene	4,000	18	99.6
Tetrachloroethene	740	0	100
1,3-Dimethylbenzene	890	27	97
1,2-Dimethylbenzene	1,300	27	98
Total VOCs[d]	270,000	94,000	65

[a]Based on calculations using extracted gas sample chemical specific analyses by Lord Corporation Laboratory. This information is also presented in Section 4.1.2.2.
[b]Based on calculation using carbon exhaust sample chemical specific analyses by Lord Corporation Laboratory.
[c]Calculated by Mass Leaving Carbon divided by Mass Entering Carbon times 100.
[d]Does not include methane; includes vinyl chloride.

downhill from EX-1 to a low spot then back up a small incline to the process trailer). During Part 2 testing activities, the condensate was periodically pumped from the extraction pipe into a waste drum. A small peristaltic pump was used to transfer the condensate through a rigid plastic hose which was inserted into the pipe through a small hole. The other end of the hose was inserted in the waste drum. When the condensate had been removed from the extraction pipe, the small hole was covered with duct tape and the waste drum was closed. Respirators and other PPE were worn during all condensate collection activities.

The condensate in the waste drum was sampled and its volume measured at the end of the Part 2 testing (just prior to the extraction phase of the slug 5 test). The volume collected was estimated at 143 L. The condensate samples were sent to the ECKENFELDER INC. laboratory in Nashville, Tennessee for analysis. The samples were analyzed for volatile organics by USEPA Method 8240 and for chloride, fluoride, nitrate + nitrate nitrogen, pH, and sulfate by USEPA methods 325.3, 340.2, 353.3, 15.01, and 375.4, respectively. The results of these tests are given as Appendix T. Using the concentration of volatile organics reported and the total volume of the condensate collected in the drum, an approximate concentration of 0.54 g/L total VOCs has been calculated. The primary VOCs reported were vinyl chloride, acetone, 1,2-dichloroethene (total), 2-butanone, trichloroethene, 4-methyl-2-pentanone, and xylenes. Other organic compounds which were detected in small quantities were methylene chloride, 1,1-dichloroethene, 1,1-dichloroethane, benzene, 2-hexanone, tetrachloroethene, toluene, chlorobenzene, and ethyl benzene. (See Appendix T for analytical report.) The concentrations of chloride, fluoride, nitrate + nitrate nitrogen, and sulfate were 219, 0.16, 1.5, and 78 mg/L, respectively. The pH was measured to be 7.10. This latter set of inorganic constituents was measured to determine the corrosivity of the condensate. This information should prove useful in the design phase when selection of materials of construction is made.

The quantity of organic compounds identified in the condensate is 77 grams of VOC material removed from under the cap. This represents less than 0.03 percent of total removed, calculated from the chemical specific analyses of the gas phase samples (without methane) using the sum of the masses from all three tests. There are some volatile organic compounds included on the list of analytes for USEPA Method 8240 which are not included in the Method TO-14 list of analytes. The

analysis of the condensate included quantification of 2-hexanone, chlorobenzene, ethylbenzene, and 1,1-dichloroethene, compounds which were not identified by either the primary or QA/QC laboratory in the extracted gas samples. Only 1,1-dichloroethene is not on the TO-14 list of analytes. Similarly, there were some airborne constituents from the extraction well not seen in the condensate, i.e., 2-propanol, 2-butanol, chloroform, and tetrahydrofuran. Only chloroform, however, is on the Method 8240 list of analytes.

4.6 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

As described in the Work Plan, several types of QA/QC samples were taken during the course of the treatability study testing. These samples included:

- Blind replicate samples submitted to the primary laboratory.
- Split replicate samples submitted to the primary laboratory and the QA/QC laboratory.
- Blind replicate samples submitted to the primary laboratory with a split replicate sent simultaneously to the QA/QC laboratory.
- Blank/background samples.
- Blind samples with known concentrations of select compounds.

All QA/QC samples were gas phase samples collected and transferred in 1 liter Tedlar® bags. The word "replicate" was used in the description of the QA/QC samples because true duplicate samples may not be possible given the potential inherent variation in soil gas extracted during vapor stripping. The qualitative and quantitative profile of a sample of extracted gas can vary over a relatively brief period of time as locations close to the extraction well deplete original VOC concentrations and streamlines from other parts of the zone of influence continuously carry VOCs of possibly different identities and concentrations to the extraction well.

4.6.1 QA/QC Data from the Toe and Crest Study--November 1991

There were three blind replicate samples sent to the primary laboratory for analysis as well as a blank and a sample with known concentrations of select compounds. Tables 4-19 through 4-21 contain the replicate results taken at TC-3 (on the toe), TC-6 (on the crest) and the extraction well, respectively. Detailed analytical information is provided in Appendix R. When concentrations are not reported, the compound was not detected at a reported limit of detection of 1 ppb. The results from TC-3 show rather good qualitative and quantitative agreement with the largest variation experienced in the cis-1,2-dichloroethene values. The results of TC-6 QA/QC replicate testing indicated vinyl chloride in one of the two samples. It was this sample that also included MIBK, toluene, and m-xylene. The fact that all the unmatched compounds appear in one sample tends to lend lends credence to its being an accurate analysis of a slightly different sample. The quantitative comparison for trichloroethene and tetrachloroethene is reasonable.

The QA/QC results from the extraction well compare very favorably both qualitatively and quantitatively. This probably accurately reflects the samples' composition. These samples were taken with the small explosion proof pump at a relatively slow rate for a total volume that was small compared to the pore volume of the landfill. There was less chance for the factors causing heterogeneity to occur in these gas samples. The samples taken at the toe and crest wells are believed to have a comparatively small zone of influence and the sampling procedures and stream line behavior could have more impact on the samples' compositions.

Table 4-22 presents the results of an ambient air sample taken at the exhaust of the portable ISVS unit after purging with ambient air until the OVA reading at the exhaust was "0" ppm. Residual levels of tetrachloroethene were found. The sample taken by the portable unit prior to the purge was TC4-5. Review of the data indicates a tetrachloroethene level of 12,000 ppb (v/v) in sample TC4-5. All other constituents were below detection limits.

The final QA/QC sample for this phase of testing was prepared by introducing calibration gas used in an OVA unit into the Tedlar® bag. The calibration gas contained: benzene, toluene, ethyl benzene, and a xylene at concentrations of 75 ppm (v/v). This approach to the creation of this QA/QC sample was a one-time,

TABLE 4-19

RESULTS OF REPLICATE SAMPLE ANALYSES FROM TC-3, ppb (v/v)

Compound	TC-3-3	TC3A-1
Chloromethane		
Vinyl chloride	460	
Trichlorofluoromethane		
Acetone[a]		43
Methylene chloride[a]		24
trans-1,2-Dichloroethene		62
1,1-Dichloroethane		
2-Butanone		
Chloroform		
cis-1,2-Dichloroethene	1,300	9,500
Tetrahydrofuran		
Benzene		
Trichloroethene	7.3	75
MIBK(4-Methyl-2-pentanone)	230	210
4-Methyl-2-Pentanol		
Toluene	100	100
Tetrachloroethene	400	120
Chlorobenzene		5.2
1,3-Dimethylbenzene (m-xylene)	140	150
Cyclohexanone		150
1,2-Dimethylbenzene (o-xylene)	83	93
1,1,2,2-Tetrachloroethane		

[a]May be a laboratory contaminant.

TABLE 4-20

RESULTS OF REPLICATE SAMPLE ANALYSES FROM TC-6, ppb (v/v)

Compound	TC-6-3	TCAA-1
Chloromethane		
Vinyl chloride		2,700
Trichlorofluoromethane		
Acetone		
Methylene chloride		
trans-1,2-Dichloroethene		
1,1-Dichloroethane		
2-Butanone		
Chloroform		
cis-1,2-Dichloroethene		
Tetrahydrofuran		
Benzene		
Trichloroethene	550	1,100
MIBK(4-Methyl-2-pentanone)		200
4-Methyl-2-Pentanol		
Toluene		350
Tetrachloroethene	6,100	5,900
Chlorobenzene		
1,3-Dimethylbenzene (m-xylene)		250
Cyclohexanone		
1,2-Dimethylbenzene (o-xylene)		
1,1,2,2-Tetrachloroethane		

TABLE 4-21

RESULTS OF REPLICATE ANALYSES FROM THE EXTRACTION WELL,[a] ppb (v/v)

Compound	CEX1-1	DD-1
Chloromethane		
Vinyl chloride	14,000	13,000
Trichlorofluoromethane		
Acetone		
Methylene chloride		
trans-1,2-Dichloroethene		
1,1-Dichloroethane		
2-Butanone		
Chloroform		
cis-1,2-Dichloroethene		
Tetrahydrofuran		
Benzene		
Trichloroethene	3,500	2,100
MIBK(4-Methyl-2-pentanone)	5,000	4,900
4-Methyl-2-Pentanol		
Toluene	3,000	2,800
Tetrachloroethene	1,100	1,000
Chlorobenzene		
1,3-Dimethylbenzene (m-xylene)	2,900	3,300
Cyclohexanone		
1,2-Dimethylbenzene (o-xylene)	1,300	1,500
1,1,2,2-Tetrachloroethane		

[a]November 1991 testing.

TABLE 4-22

RESULTS (AMBIENT) AND BLIND CALIBRATION GAS SAMPLE ANALYSES, ppb (v/v)

Compound	CC-1 (Ambient)	FF-1 (Cal Gas)[a]
Chloromethane		
Vinyl chloride		1,100
Trichlorofluoromethane		
Acetone		
Methylene chloride		
trans-1,2-Dichloroethene		
1,1-Dichloroethane		
2-Butanone		
Chloroform		
cis-1,2-Dichloroethene		
Tetrahydrofuran		
Benzene		550
Trichloroethene		630
MIBK(4-Methyl-2-pentanone)		250
4-Methyl-2-Pentanol		
Toluene		1,300
Tetrachloroethene	7,700	250
Chlorobenzene		
1,3-Dimethylbenzene (m-xylene)		500
Cyclohexanone		
1,2-Dimethylbenzene (o-xylene)		1,200
1,1,2,2-Tetrachloroethane		

[a]Calibration gas used was BETX which contains 75 ppm (mole %) each of benzene, ethyl benzene, toluene, and o-xylene.

field designed effort and not a formal protocol. As evidenced by the resultant data, the approach was not very successful. (See Table 4-22.) Some additional compounds (consistent with those previously identified in the field samples) were also present in this QA/QC sample. Those included: trichloroethane, MIBK, tetrachloroethane, and tetrachloroethene.

4.6.2 QA/QC Data from the Various Treatability Study Tests at the Landfill (March 1992)

The longer, more complex series of tests performed on the landfill itself involved both internal and external QA/QC samples. During the 75-hour test, two blind replicates, one split, and two blind replicates with splits to the outside QA/QC laboratory were analyzed. Also two background checks of ambient air were taken. Two blind duplicates were sent to Twin City Testing, the laboratory that analyzed the methane samples. During the 8-hour passive vent test, blind replicates were taken. There were no outside QA/QC samples taken during this brief test. A methane replicate was sent to Twin City Testing. The replicates sent to the primary laboratory and Twin City Testing were designated to be used only if there were a problem with the primary sample. During the slug test, two blind replicates were analyzed by the primary laboratory and one blind replicate with split to the outside QA/QC laboratory was analyzed.

The total xylene number reported by Ross Laboratories, the outside QA/QC laboratory, should be compared to the sum of the 1,3-dimethylbenzene (m-xylene) and 1,2-dimethylbenzene (o-xylene) reported by the Lord Corporation Laboratory. For more detailed analytical information see Appendices I and P.

4.6.2.1 Results of QA/QC Testing from 75-hour Test. The results of the various QA/QC test samples are provided in Tables 4-23 through 4-30. The sequence of the Tables 4-23 through 4-28 reflects the sampling time, increasing from the start-up at time zero. Tables 4-29 and 4-30 are ambient (background) samples taken within an hour of each other in the breathing zone near carbon exhaust and in the breathing zone at the extraction well, respectively. Table 4-31 contains the results of the blind duplicate samples sent to Twin City Testing Corporation for methane analysis. Agreement is excellent for the methane concentrations determined for the replicate samples.

Table 4-23

Blind Replicate Analyses for Extraction Well EX-1 Sample

at 5 Hours into the 75-Hour Test

	Sample: EX-08	Sample: EX-09	
	Run Date*: 3/26/92	Run Date*: 3/26/92	
Analytical Laboratory	LORD CORP	LORD CORP	
Compound	Concentration	Concentration	Concentration
	ppb(v/v)	ppb(v/v)	ppb(v/v)
Chloromethane			
Vinyl Chloride	4600000	7700000	
Acetone			
2-Propanol(Isopropanol)	1000	1100	
1,2-Dichloroethene(Total)	3000000	4200000	
1,1-Dichloroethane	4300	4400	
2-Butanone	8200	8300	
2-Butanol(sec-Butanol)	2000	1900	
Chloroform			
Tetrahydrofuran	72000	77000	
Benzene	6100	6700	
Trichloroethene	180000	180000	
4-Methyl-2-pentanone	140000	150000	
Toluene	110000	110000	
Tetrachloroethene	8000	8800	
Chlorobenzene			
1,3-Dimethylbenzene	29000	25000	
Cyclohexanone			
1,2-Dimethylbenzene	28000	33000	
1,1,2,2-Tetrachloroethane			
Methylene Chloride			
Xylenes (Total)			
4-Methyl-2-pentanol			
Total VOCs	8188600	12506200	
Elapsed time from start of 75-hour ISVS test for sample collection (hours			5

Table 4-24

Blind Replicate Analyses with Split Sample to Outside QA/QC Laboratory for Monitoring Probe EP-12 at 20 Hours into the 75-Hour Test

	Sample:EP12-03	Sample:EP12-04	Sample: EP12-05
	Run Date*: 3/26/92	Run Date*: 3/26/92	Run Date*: 3/30/92
Analytical Laboratory	LORD CORP	LORD CORP	ROSS LAB
Compound	Concentration	Concentration	Concentration
	ppb(v/v)	ppb(v/v)	ppb(v/v)
Chloromethane			
Vinyl Chloride	12000	2700	490
Acetone			44
2-Propanol(Isopropanol)			
1,2-Dichloroethene(Total)	12000	3200	450
1,1-Dichloroethane	2600	2400	2200
2-Butanone	900	800	
2-Butanol(sec-Butanol)			
Chloroform			
Tetrahydrofuran	1400	1300	
Benzene			36
Trichloroethene	3100	1300	240
4-Methyl-2-pentanone	1100		95
Toluene	1900	1200	340
Tetrachloroethene			320
Chlorobenzene			
1,3-Dimethylbenzene	1100	600	
Cyclohexanone			
1,2-Dimethylbenzene	500		
1,1,2,2-Tetrachloroethane			
Methylene Chloride			240
Xylenes (Total)			1400
4-Methyl-2-pentanol			3200
Total VOCs	36600	13500	9055
Elapsed time from start of 75-hour ISVS test for sample collection (hours			19.97

Table 4-25

Blind Replicate Analyses for Sample at Monitoring Probe EP12

at 74 Hours into the 75-Hour Test

	Sample: EP12-07	Sample:EP12-08	
	Run Date*: 3/28/92	Run Date*: 3/28/92	
Analytical Laboratory	LORD CORP	LORD CORP	
Compound	Concentration	Concentration	
	ppb(v/v)	ppb(v/v)	
Chloromethane			
Vinyl Chloride	4900	4900	
Acetone	2000		
2-Propanol(Isopropanol)			
1,2-Dichloroethene(Total)	2500		
1,1-Dichloroethane	1600	1700	
2-Butanone			
2-Butanol(sec-Butanol)			
Chloroform			
Tetrahydrofuran	2500	800	
Benzene			
Trichloroethene			
4-Methyl-2-pentanone			
Toluene			
Tetrachloroethene	750		
Chlorobenzene			
1,3-Dimethylbenzene	1600		
Cyclohexanone			
1,2-Dimethylbenzene	1300		
1,1,2,2-Tetrachloroethane			
Methylene Chloride			
Xylenes (Total)			
4-Methyl-2-pentanol			
Total VOCs	17150	7400	
Elapsed time from start of 75-hour ISVS test for sample collection (hours			73.67

Table 4-26

Split Sample from Extraction Well EX-1 at 24 Hours into the 75-Hour Test

	Sample: EX-15	Sample: EX-17	
	Run Date*: 3/26/92	Run Date*: 3/30/92	
Analytical Laboratory	LORD CORP	ROSS LAB	
Compound	Concentration	Concentration	Concentration
	ppb(v/v)	ppb(v/v)	ppb(v/v)
Chloromethane			
Vinyl Chloride	5400000	11000000	
Acetone		16000	
2-Propanol(Isopropanol)		17000	
1,2-Dichloroethene(Total)	3100000	11000000	
1,1-Dichloroethane	6700	7700	
2-Butanone	12000	23000	
2-Butanol(sec-Butanol)	1000	26000	
Chloroform	950	1600	
Tetrahydrofuran	7000		
Benzene	7400	4200	
Trichloroethene	340000	480000	
4-Methyl-2-pentanone	150000	280000	
Toluene	120000	200000	
Tetrachloroethene	13000	6200	
Chlorobenzene			
1,3-Dimethylbenzene	22000		
Cyclohexanone			
1,2-Dimethylbenzene	33000		
1,1,2,2-Tetrachloroethane			
Methylene Chloride		58000	
Xylenes (Total)		150000	
4-Methyl-2-pentanol		570000	
Total VOCs	9213050	23839700	
Elapsed time from start of 75-hour ISVS test for sample collection (hours)			24.33

Table 4-27

Blind Replicate Analyses for Carbon Exhaust Sample

at 73.5 Hours into the 75-Hour Test

	Sample: C0-06	Sample: CO-O7	
	Run Date*: 3/28/92	Run Date*: 3/28/92	
Analytical Laboratory	LORD CORP.	LORD CORP	
Compound	Concentration	Concentration	
	ppb(v/v)	ppb(v/v)	
Chloromethane			
Vinyl Chloride	11000000	10000000	
Acetone			
2-Propanol(Isopropanol)			
1,2-Dichloroethene(Total)		1500	
1,1-Dichloroethane			
2-Butanone			
2-Butanol(sec-Butanol)			
Chloroform			
Tetrahydrofuran			
Benzene			
Trichloroethene		1700	
4-Methyl-2-pentanone	900	800	
Toluene		650	
Tetrachloroethene			
Chlorobenzene			
1,3-Dimethylbenzene		1100	
Cyclohexanone			
1,2-Dimethylbenzene		500	
1,1,2,2-Tetrachloroethane			
Methylene Chloride			
Xylenes (Total)			
4-Methyl-2-pentanol			
Total VOCs	11000900	10006250	
Elapsed time from start of 75-hour ISVS test for sample collection (hours			73.5

Table 4-28

Blind Replicate Analyses with Split Sample to Outside QA/QC Laboratory for Extraction Well EX-1 at 74 Hours into the 75-Hour Test

	Sample: EX-18	Sample: EX-21	Sample: EX-19
	Run Date*: 3/28/92	Run Date*: 3/28/92	Run Date*: 3/31/92
Analytical Laboratory	LORD CORP	LORD CORP	ROSS LAB
Compound	Concentration	Concentration	Concentration
	ppb(v/v)	ppb(v/v)	ppb(v/v)
Chloromethane			
Vinyl Chloride	2600000	2800000	11000000
Acetone	5100	5400	5600
2-Propanol(Isopropanol)			3400
1,2-Dichloroethene(Total)	1900000	2600000	1900000
1,1-Dichloroethane	3800	3800	4400
2-Butanone	8300	11000	55000
2-Butanol(sec-Butanol)	5100	5900	
Chloroform	750	850	1500
Tetrahydrofuran	51000		
Benzene	5500	5900	2700
Trichloroethene	330000	410000	610000
4-Methyl-2-pentanone	440000	630000	370000
Toluene	240000	230000	150000
Tetrachloroethene	17000	15000	5100
Chlorobenzene			
1,3-Dimethylbenzene	18000	29000	
Cyclohexanone			
1,2-Dimethylbenzene	41000	35000	
1,1,2,2-Tetrachloroethane			
Methylene Chloride			80000
Xylenes (Total)			120000
4-Methyl-2-pentanol			300000
Total VOCs	5665550	6781850	14607700
Elapsed time from start of 75-hour ISVS test for sample collection (hours			74.17

Table 4-29

Results of Ambient Air Testing in Vicinity of Carbon Exhaust at 73 Hours into the 75-Hour Test

	Sample: QC0-01		
	Run Date*: 3/28/92		
Analytical Laboratory	LORD CORP		
Compound	Concentration		
	ppb(v/v)		
Chloromethane			
Vinyl Chloride			
Acetone			
2-Propanol(Isopropanol)	* *		
1,2-Dichloroethene(Total)			
1,1-Dichloroethane			
2-Butanone			
2-Butanol(sec-Butanol)	* *		
Chloroform			
Tetrahydrofuran			
Benzene			
Trichloroethene	* *		
4-Methyl-2-pentanone	* *		
Toluene	* *		
Tetrachloroethene			
Chlorobenzene			
1,3-Dimethylbenzene	* *		
Cyclohexanone			
1,2-Dimethylbenzene			
1,1,2,2-Tetrachloroethane			
Methylene Chloride			
Xylenes (Total)			
4-Methyl-2-pentanol			
Total VOCs			
Elapsed time from start of 75-hour ISVS test for sample collection (hours			73.3

* for initial analysis

* * Concentration is above the detection limit but below LOQ (500 ppb).

Table 4-30

Results of Ambient Air Testing on Cap Near Extraction Well EX-1

at 73 Hours into the 75-Hour Test

	Sample: QEX-01		
	Run Date*: 3/29/92		
Analytical Laboratory	LORD CORP		
Compound	Concentration		
	ppb(v/v)		
Chloromethane			
Vinyl Chloride			
Acetone			
2-Propanol(Isopropanol)			
1,2-Dichloroethene(Total)	550		
1,1-Dichloroethane			
2-Butanone			
2-Butanol(sec-Butanol)	1400		
Chloroform			
Tetrahydrofuran			
Benzene			
Trichloroethene			
4-Methyl-2-pentanone			
Toluene			
Tetrachloroethene			
Chlorobenzene			
1,3-Dimethylbenzene			
Cyclohexanone			
1,2-Dimethylbenzene			
1,1,2,2-Tetrachloroethane			
Methylene Chloride			
Xylenes (Total)			
4-Methyl-2-pentanol			
Total VOCs	1950		
Elapsed time from start of 75-hour ISVS test for sample collection (hours			73.3

TABLE 4-31

RESULTS OF BLIND REPLICATE ANALYSES FOR METHANE[a]

Sample	Location	% Methane (v/v)
MEP12-04A	EP-12	30
MEP12-05A	EP-12	27
MEX-04A	EX-1	7
MEX-05A	EX-1	8

[a]Performed by Twin City Testing Corporation, St. Paul, Minnesota.

Table 4-23 presents the results of a blind replicate sample taken after five hours of stripping operations. The agreement is very good throughout. The EX-09 sample is somewhat higher in all constituents except for 1,3-dimethylbenzene. The approximately 50 percent higher total VOC value, however, can be accounted for mainly by the difference in the vinyl chloride concentration and, to a lesser extent, the total 1,2-dichloroethene (i.e., isomer not specified).

Table 4-24 presents data taken at 20 hours into the 75-hour test. The data are from the farthest monitoring probe, EP12, and include both a blind replicate and a split sample with the outside QA/QC laboratory. Again, the greatest discrepancies on an inter- and intra-laboratory basis occur for the vinyl chloride and 1,2-dichloroethene (total) values. The EP12-03 sample is consistently higher in the constituents reported compared to the blind replicate sample, EP12-04. Overall, quantitation levels from the QA/QC laboratory are closer to the lower concentration EP12-04 sample, although qualification (i.e., analyte identification) does not completely agree. In some cases, dilution of the sample to obtain a linear response (i.e., on the calibration curve) for the compounds present in high concentrations may have caused those constituents present in lower concentrations to be diluted below detection limits. Table 4-25 presents data taken 74 hours into the 75 hour test from EP12. Agreement between the samples is not as good as would be expected. Comparing the data to those in Table 4-24, also from EP12, it appears that the analysis of EP12-07 is more consistent.

Table 4-26 contains the results of a split sample analysis taken from the gas at the extraction well after approximately one day of operations. The Ross data were generally higher than the Lord Corporation data. Again, the differences in the vinyl chloride and 1,2-dichloroethene levels account for the majority of the discrepancy.

Table 4-27 provides the results of a blind duplicate sample taken at 73.5 hours into the run from the activated carbon exhaust. The agreement between the vinyl chloride concentrations is evident. The discrepancy in quantifying the other low level constituents could be ascribed to the dilution factors required to quantitate the vinyl chloride.

Table 4-28 provides data taken at the extraction well near the end of the 75-hour test (i.e., 74.2 hours). These data are from a blind replicate and split sample. Again overall the Ross total VOC datum is higher, reflecting the vinyl chloride concentration (total 1,2-dichloroethenes values are comparable). Overall the qualification and quantification are in relatively good agreement.

Table 4-29 presents the background air data taken in the breathing zone at the carbon exhaust. No compounds are above the limit of quantification, 10 ppb. Table 4-30 presents the background on data (in the breathing zone) at the extraction well in same format. There was 550 ppb of 1,2-dichloroethene measured in the sample and 1,400 ppb of 2-butanol. Again, there were no other compounds present above the limit of quantitation of 10 ppb.

4.6.2.2 QA/QC Data from the Slug Tests. Several QA/QC samples were taken during the slug tests. During the second 1-hour slug test (also called Slug 2), a blind replicate was sent to the primary laboratory. During the 15-hour slug test (also called Slug 5), blind replicate samples were sent to the primary laboratory. A split sample from the same sampling event was sent to the outside QA/QC laboratory. Details of the chemical specific analyses are provided in Appendix P. Blind replicate samples for methane analyses were taken during the 5-hour slug test and the 15-hour slug test.

Table 4-32 presents the data for the replicate analyses for the second 1 hour slug test. There is generally good qualitative and quantitative agreement between the two sets of results. Again, the contaminant transfer and sampling procedure mechanisms in relatively small volumes would lend themselves to the creation of relatively homogenous replicate samples. Similarly, Table 4-33, with the results of the blind replicate and split samples, indicates good qualitative agreement between the two sets of Lord results and good agreement also with the Ross results. Again, the Ross laboratory results are higher in the total VOCs reported. The majority of the difference is in the vinyl chloride and trichloroethene results.

Table 4-34 presents the results of the blind methane replicate analyses. The agreement in both cases is very good.

Table 4-32

Replicate Analyses of Sample Taken During Second 1-Hour Slug Test

(1.25 hours contact time)

	Sample: EX-31	Sample: EX-32	
	Run Date*: 3/31/92	Run Date*: 3/31/92	
Analytical Laboratory	LORD CORP	LORD CORP	
Compound	Concentration	Concentration	
	ppb(v/v)	ppb(v/v)	
Chloromethane			
Vinyl Chloride	1100000	1300000	
Acetone	4200	4500	
2-Propanol(Isopropanol)			
1,2-Dichloroethene(Total)	1800000	2000000	
1,1-Dichloroethane	5400	5800	
2-Butanone	8100	8700	
2-Butanol(sec-Butanol)	10000	8500	
Chloroform	950	1000	
Tetrahydrofuran	39000	39000	
Benzene	4300	4500	
Trichloroethene	320000	350000	
4-Methyl-2-pentanone	110000	130000	
Toluene	180000	130000	
Tetrachloroethene	10000	11000	
Chlorobenzene			
1,3-Dimethylbenzene	35000	38000	
Cyclohexanone		1600	
1,2-Dimethylbenzene	32000	33000	
1,1,2,2-Tetrachloroethane			
Methylene Chloride			
Xylenes (Total)			
4-Methyl-2-pentanol			
Total VOCs	3658950	4065600	
Elapsed time from start of second 1-hour slug test for sample collection (hours)			
	1.25	1.29	

Table 4-33

Blind Replicate and Split Sample Analyses for Sample Taken During 15-Hour Slug Test

	Sample: EX-39	Sample: EX-40	Sample: EX-41
	Run Date*: 4/2/92	Run Date*: 4/2/92	Run Date*: 4/30/92
Analytical Laboratory	LORD CORP	LORD CORP	ROSS LAB
Compound	Concentration	Concentration	Concentration
	ppb(v/v)	ppb(v/v)	ppb(v/v)
Chloromethane			
Vinyl Chloride	1900000	2000000	3100000
Acetone	3800	3800	1500
2-Propanol(Isopropanol)			
1,2-Dichloroethene(Total)	2200000	2300000	2800000
1,1-Dichloroethane	4300	4200	4500
2-Butanone	5500	5600	
2-Butanol(sec-Butanol)	5500	5900	
Chloroform	700	700	1200
Tetrahydrofuran	57000	61000	
Benzene	5800	5600	3700
Trichloroethene	350000	370000	620000
4-Methyl-2-pentanone	150000	160000	130000
Toluene	190000	180000	170000
Tetrachloroethene	13000	12000	7900
Chlorobenzene			
1,3-Dimethylbenzene	52000	60000	
Cyclohexanone	850	1800	
1,2-Dimethylbenzene	54000	48000	
1,1,2,2-Tetrachloroethane			
Methylene Chloride			100000
Xylenes (Total)	106000	107600	140000
4-Methyl-2-pentanol			3400
Total VOCs	5098450	5326200	7082200
Elapsed time from start of 15-hour slug test for sample collection (hours)			
	14.94	14.97	15

TABLE 4-34

RESULTS OF BLIND REPLICATE SAMPLE ANALYSES FOR METHANE (TAKEN DURING SLUG TESTING)

Test	Methane Conc., % v/v
Slug Test 4 (5 hours)	0.6
	0.8
Slug Test 5 (15 hours)	2
	2

4.6.3 Summary of QA/QC Results

The Quality Assurance Project Plan, QAPP, developed for the Treatability Study Work Plan, called for a minimum of 10 percent blind replicates and daily blind blank (background) samples for field QA/QC. The QAPP discussed the potential difficulty in obtaining truly duplicated samples for analysis. No field spiking was required. The Quality Objectives anticipated that 80 percent of the data were needed to pass quality assurance testing to maintain a valid study and permit the use of the data in later phases of the project.

The November 1991 testing generated a total of 32 samples for chemical specific analysis which were forwarded to Lord Corp. There were four replicates generated for analysis by the laboratory. This is 12.5 percent. Given the truncated study due to the methane, no outside QA/QC was performed on the VOC analyses. (Outside QA/QC was beyond the requirements of the QAPP but was performed during the March 1992 testing to study further the quality of the data.) A background sample and blind calibration gas sample were also taken. The agreement of the replicated data (Section 4.6.1) exhibited was comparable to that seen at other sites. There were eight blind replicate samples sent to Twin City Testing for the analysis of methane. There was one sample submitted for a QA/QC, providing a ratio of one in eight or 12.5 percent. One sample was sent to Twin City Testing for methane analysis upon the initial shutdown of the blowers on November 6, 1991.

The March 1992 data generated a total of 47 samples for VOC chemical specific analysis (31 samples from the 75 hour test; 4 samples from the passive vent test; and 12 samples from the slug test). A total of 7 blind replicates were taken for analysis by the primary laboratory and 4 replicates were shipped to the outside QA/QC laboratory for a total of 23 percent. There were two background samples taken as well as a laboratory background sample. These data were supplemented by multiple ambient air monitoring samples taken at various locations on a daily basis. There were a total of 26 methane samples taken over all three tests. A total of 3 blind replicates were forwarded to Twin City Testing for a total of 11.5 percent QA/QC for methane analysis.

Sample data received from the primary laboratory were reviewed in detail. Given the levels of VOCs in the samples, most samples required two dilutions. Data were

reported in two data sets. These sets were reduced to one data set per sample. The combined data set for each sample was produced by taking the best data for each individual compound based on dilution factors and quantitation limits.

After the data were reviewed and individual compounds deleted if they failed to meet the various criteria listed (e.g., present in blank above a given level, reported concentration below LOQ, etc.), only one set of data appeared unusable. This data set was for the second sample taken during Slug Test 1 (at 25 percent volume extraction, see Table 4-10). There were a total of 47 samples taken during testing for chemical specific VOC analyses (not counting the QA/QC samples) so this represents 98 percent validity on a per sample basis (46 of 47). The total number of individual compounds eliminated from various sets of data was 127. Based upon an estimated total of 940 individual compound analyses (47 sets x 20 compounds per set), this represents 13 percent or a 87 percent validity on a per compound basis. This is in excess of the target 80 percent validity required by the QAPP.

4.0 RESULTS AND DISCUSSION

The results of the four tests (75-hour ISVS; 8-hour passive vent; pulse/slug; and toe/crest) performed for this treatability study are presented in this section with appropriate discussion. Each test is treated individually in Sections 4.1, 4.2, 4.3, and 4.4, respectively; a discussion of the test results is included at the end of each section. Section 4.5 contains results and evaluation of the carbon performance data and of the condensate collection data. All of the QA/QC data are reported in Section 4.6 with appropriate discussion. Section 5.0, Summary and Conclusions, is used to discuss the results of the four tests as they interrelate and to discuss conclusions that can be drawn from these results. Application of the data to the design of the treatment system is left to a later phase of the Remedial Design project. Section 6.0 is a photographic log of pictures taken throughout the November 1991 and March 1992 activities.

4.1 75-HOUR ISVS TEST RESULTS

This section presents the results of the 75-hour ISVS test. The data from this test are presented as either process data or chemical data. A discussion of the results is given at the end of this section. The duration of the test was reduced from the planned 96 hours to 75 hours to permit testing of the site using the passive vent well configuration within the same total time frame. As was noted in the previous section, the presence of methane precluded the scheduled testing to determine which configuration was applicable to the site. A field decision during the site preparation was made to have the drillers install wells on a configuration which would allow the testing of vapor stripping at the site both with and without passive vent wells without additional breaching of the cap. A discussion of the equipment and materials used for the test is presented in Section 2.3; the test design is discussed in Section 3.2.

4.1.1 Process Data

Process data were taken during the 75-hour ISVS test at the ISVS Mobile Unit (also called the process trailer) and at the monitoring points beneath the landfill cap at EX-1, PV-2, EP-11, and EP-12. Table 4-1 shows the parameters measured during

5.0 SUMMARY AND CONCLUSIONS

The Site is Amenable to In Situ Vapor Stripping

- Approximately 290 kg of VOCs (not including methane) were removed from the site during testing. The major constituents removed from the landfill were vinyl chloride and 1,2-dichloroethene, averaging 80 percent or more of the total mass. An additional 1,480 kg of methane were removed. (See Table 5-1). Table 5-2 provides the average VOC concentrations in the extracted gas from each test. The methane and vinyl chloride will require specific consideration during the design phase with respect to emission controls.

There Appears to be Adequate, Though Limited, Pneumatic Permeability Through The Edges/Sides of the Landfill to Permit Implementation of Vapor Stripping without Installing Passive Vents

- The top of the landfill is impermeable because of the geomembrane/clay cap. The groundwater underlying the landfill forms an impermeable boundary at the bottom of the landfill. The pneumatic permeability of the side/edges can be estimated in several ways. If the landfill were completely "tight", the removal of approximately 0.2 pore volumes should result in vacuum under the extremities of the cap of approximately 0.2 atm or 81 in.W.C. This was not the case. The vacua at probe EP11 and EP12 were approximately 15 to 20 in.W.C. at the end of the 75 hour run--significantly less than the 81 inches predicted for the air tight configuration. Thus it would seem that there is an external source of air into the landfill when a vacuum is applied. In all tests, the vacuum readings were essentially the same in probe EP11 and as in probe EP12 which are approximately 100 feet apart. Thus no appreciable pressure gradient was measured horizontally beneath the cap which lends support to the supposition that the cap liner was tight and that air came in through the sides of the landfill. It is because of the influx of air into the system from the outside that the porosity can not be calculated. The use of an ideal gas model and the assumption of no leakage from the top, bottom, or

TABLE 5-1

SUMMARY OF VOCs AND METHANE REMOVAL DURING TESTING

Test	VOC, kg	Methane
75-hour	265	1,390
Passive Vent	21.5	91.4
Slug	3.11	1.10
Condensate	0.0779	--
TOTAL	290	1,480

TABLE 5-2

AVERAGE EXTRACTED GAS CONCENTRATION ON A TEST SPECIFIC BASIS

Test	Total VOC, kg	Total Volume Gas Extracted, std m^3	Average Extracted Gas Concentrations	
			µg/L	ppm v/v[a]
75-Hour	265	9,140	29	9,000
Passive Vent	21.5	821	26	8,100
Slug	3.11	153	20	6,300

[a]Based upon the average molar volume of vinyl chloride and 1,2-dichloroethene.

periphery would ultimately yield the volume from which the gas was removed. Performing this calculation, however, using the 75 hour data, results in a value greater than the volume of the fill, thus indicating that the air tight assumption was incorrect and air is leaking around the edges of the domain. It is this air that enters the landfill which carries the VOCs from the landfill to the extraction well for removal.

- A rough approximation to the superficial gas velocity through the perimeter can be made. This is based upon the 3 percent leakage factor determined when the isolation created by the passive vent operation was assessed. If one were to ascribe all the "leakage" into the volume surrounding the extraction well, created by the passive vents, to external (i.e., outside of the landfill) air sources, the 3 percent factor could be applied to the 75 hour test operation. Using the 75 scfm value for flow at the extraction well, a maximum flow rate of 2.25 scfm could be attributed to leakage. The area of the clay perimeter walls is approximately 44,000 ft^2 [(2 x 250 x 20) + (2 x 750 x 20)]. This results in a gas velocity of 5.1 x 10^{-5}ft/min. This value is, of course, an approximation, but is available for use in the design phase.

- Appendix U contains the calculations used to determine the percent isolation resulting from the three passive vent configuration. The vents appear to provide 97 percent isolation of the prescribed volume (i.e., 97 percent of the gas flow drawn from the extraction well comes from the three passive vents.) If needed during remediation, it appears that a passive vent scenario would be well suited to the site. For example, if during stripping operations, the vacuum would steadily increase and the air flow would steadily decrease, this would be an indication that there was insufficient air in the system to continue operation at design parameters. At that time another source of air may need to be introduced. This could be achieved by the use of passive vents. However, the pilot test results provide no indication that passive vents should be necessary.

The Vacuum/Flow Relationship Needed in Design Work was Determined for the Landfill

- The pneumatic permeability of the soil under the cap could not be determined from the 75 hour test since only approximately 0.2 pore volume of air was removed and the system was not anticipated to be at steady state. However, consistent with recent findings, a non-Darcian approach to the flow/vacuum relationship was applied to the data generated during the passive vent test where 4.5 pore volumes were exchanged. (See Appendix V for a discussion of the model and ramifications of non-Darcian behavior). Figure 5-1 provides a graphic representation of the flow/vacuum relationship. The equation of the curve is given below the figure with an explanation of the coefficients. The goodness of fit, r^2, for these data is 0.9699, where 1.0000 is a perfect fit. This equation,

$$V = -0.000209Q + 0.0000183Q^2$$

can be used in future design work where flow/vacuum relationships are needed.

The Effective Diffusion Constant, Necessary to Develop the Performance-Based Clean-Up Criteria Contained in the Record of Decision (ROD), for the Landfill was Determined

- It is well known that the end of an on site vapor stripping remediation can be controlled by non-equilibrium kinetics such as desorption and diffusion. The data generated from the slug test permit the preliminary calculation of the effective diffusion constant (using average total VOC data). In turn, diffusion constant will help determine how long the system should be shut off to evaluate non equilibrium effects (as manifested by "spiking" of the VOC levels upon system turn on). A time constant of 1.04 $hour^{-1}$ was calculated. (See Appendix U). The applicable range is probably 0.5 $hour^{-1}$ to 2.0 $hour^{-1}$.

- The heterogeneous nature of the fill precluded obtaining a meaningful estimate of the mass of VOCs present. Increased numbers of samples were

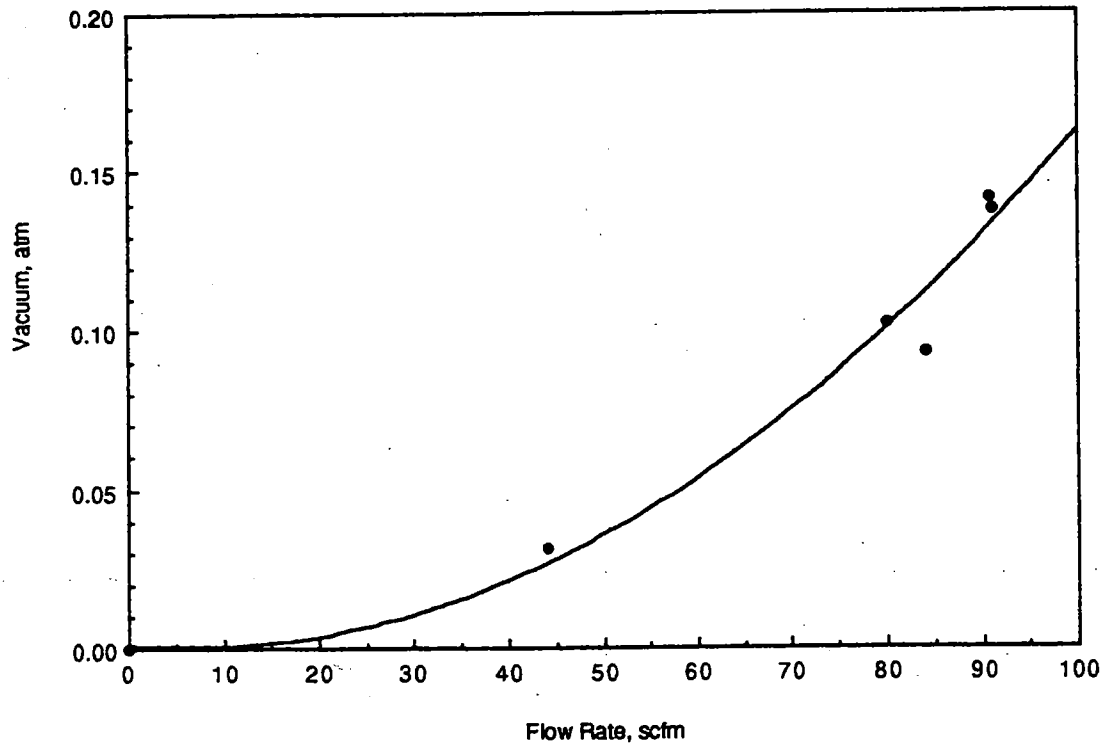


Figure 5-1. Passive Vent Test: Vacuum versus Flow Rate at Extraction Well EX-1

A least squares fit of these data to an equation describing non-Darcian behavior generates the equation:

$V_w = -0.000209Q + 0.0000183Q^2, \quad r^2 = 0.9699$

The equation is given by $V_w = A_1Q + A_2Q^2$

where:

- V_w is wellhead vacuum in atmosphere (atm)
- Q is the gas flowrate in standard cubic feet per minute (scfm)
- A_1 is the viscous resistance coefficient, relating to viscous resistance and several system-specifc parameters
- A_2 is the inertial resistance coefficient, relating to inertial resistance and several system-specific parameters
- r^2 indicates goodness of fit. 1.0000 is a perfect fit

not the answer since the cap would have to be breached for each sample collected. Therefore, the ROD was written to target this concern by using performance-based criteria to establish the end of remediation. From the performance identified during the treatability study as a result of the presence of an integral cap, it becomes even more essential to minimize breaching of the cap. Indeed, one target of the design phase should be to determine if it is feasible to create a design with significantly fewer extraction wells (i.e., breaches of the cap) than originally estimated, given the 200 plus foot radius of influence measured during this treatability study.

While Both the Toe and Crest Areas are Candidates for Vapor Stripping, Each Area has Some Extenuating Circumstances Which Need to be Addressed in the Design Phase

- The volatile compounds identified at the toe and crest locations are consistent with those identified beneath the cap and are amenable to vapor stripping. Although nonequilibrium effects preclude obtaining any direct relationship between extracted concentrations and residual soil values, the general behavior of the toe and crest locations during the treatability testing indicates substantially less volatile material present. The hydrogeology in the toe area, i.e., the shallow, fluctuating groundwater table, would require the evaluation of horizontal extraction wells (i.e., trenches) during the design phase. Also, attention would need to be given to the potential clogging of the toe area well screens. This was experienced during the treatability study.

- The crest area initially seems amenable to vertical well installation. The crest wells exhibited none of the groundwater related problems of the toe area wells. However, it should be noted that, based upon the treatability study, the zone of inference of each crest well was very limited. Specifically, while the three crest wells were approximately 10 feet apart, no vacuum was detected at adjacent well(s) during treatability study operations using the portable ISVS unit. This behavior will need to be addressed in the design phase.

6.0 PHOTOGRAPHIC LOG

The following photographs were taken on site during the November 1991 and March 1992 testing. These specific photographs were selected to help the reader who may be unfamiliar with the site to understand the logistics better. There are also photographs of the vapor stripping system and associated components including the mobile unit itself, the portable unit, wells/probes, the carbon treatment unit, monitoring equipment, etc. Each photograph is captioned and dated.

FIGURE 6-1 Long View of Site Before System Startup in November 1991. Foreground Towards Right is Toe Area. Elevated Ground on Upper Left is Crest Area

FIGURE 6-2 Close-Up of Mobile Vapor Stripping Unit Using Initial Piping Configuration, Before November 1991 Start-Up. Activated Carbon Off-Gas Treatment Unit is Also Shown on the Right Hand Side of the Photograph

FIGURE 6-3 Close-Up of Toe Well, TC-2, with Portable ISVS Unit. Note Personnel Using PPE, Mobile Communications, and Safety Markings on Electrical Cable (Lower Left Hand of Photograph) (November 1991)

FIGURE 6-4 Crest Well, TC-7, with Portable Vapor Stripping Unit and Sample Storage Container for Tedlar® Bags (November 1991)

FIGURE 6-5 Long View of Reconfigured Mobile Unit Including Stack Extension on Repositioned Activated Carbon Unit, Health and Safety Equipment Storage Trailer, Site Building, and Security Fencing (March 1992)

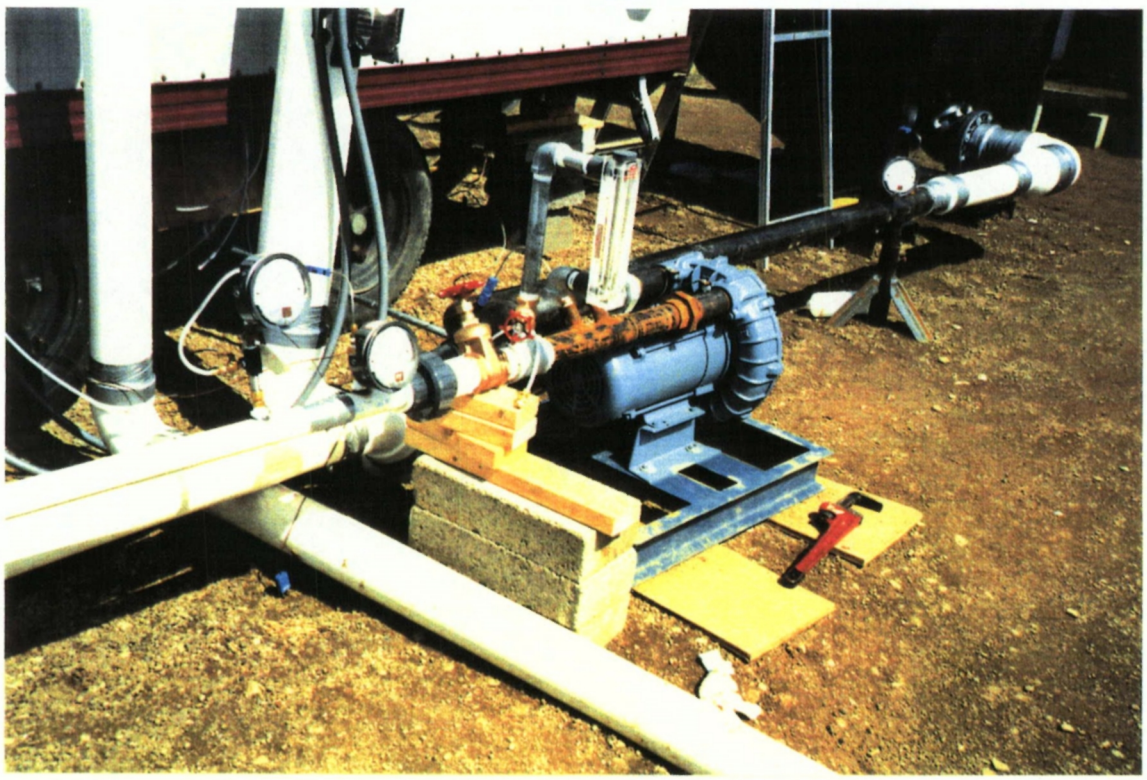


FIGURE 6-6 Close-Up of Explosion Proof Blower with Additional Flow Monitoring and Pressure/Vacuum Monitoring Gauges. Thermocouples (Blue Probes) and Opacity Monitor on Line Also (March 1992)

FIGURE 6-7 Extraction Well, EX-1, During Sampling Event (March 1992)

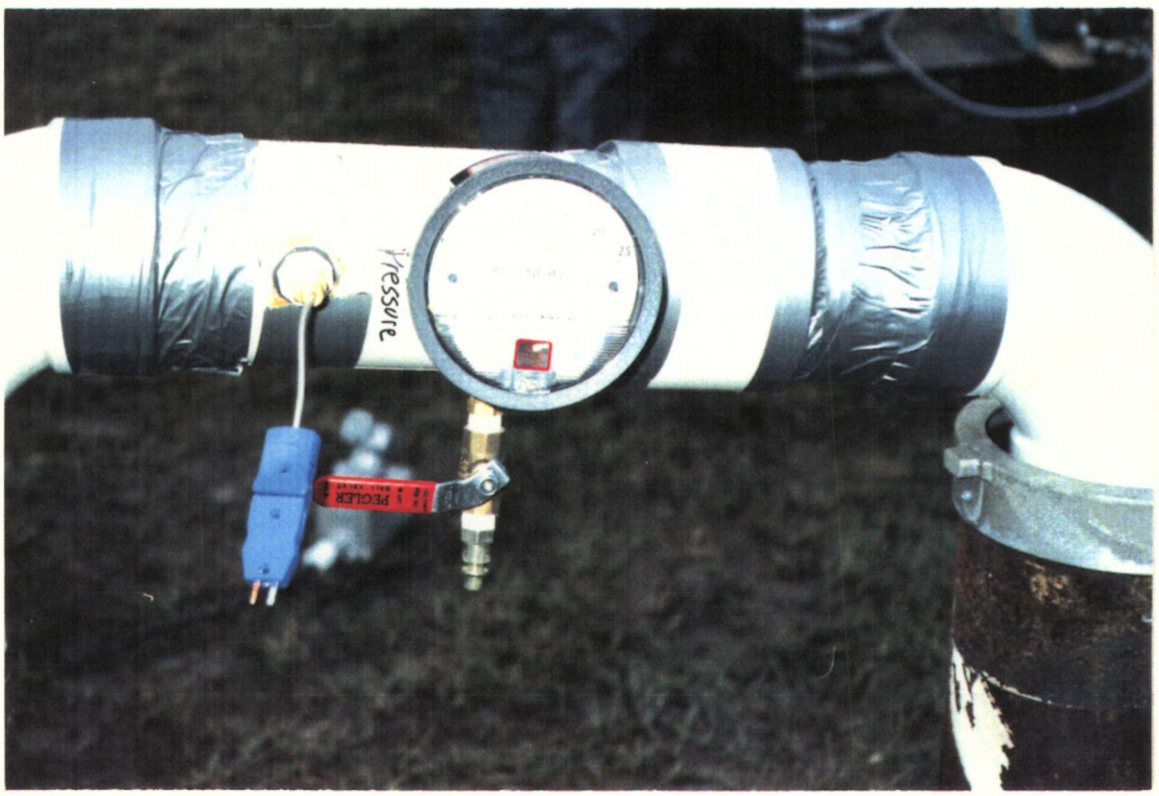


FIGURE 6-8 Close-Up of Extraction Well, EX-1, Early in 75-Hour Testing. Note Vacuum Gauge, Thermocouple, and Sampling Port (March 1992)

FIGURE 6-9 Monitoring Probe, EP-12, Vacuum Reading from Manometer Prior to Tedlar® Bag Sampling. Flag is continuous Indicator of Prevailing Wind Direction (March 1992)

FIGURE 6-10 Sampling into Tedlar® Bag Using Explosion Proof Sampling Pump (March 1992)

FIGURE 6-11 Preparing for Sampling of the Exhaust from Activated Carbon Unit (March 1992)

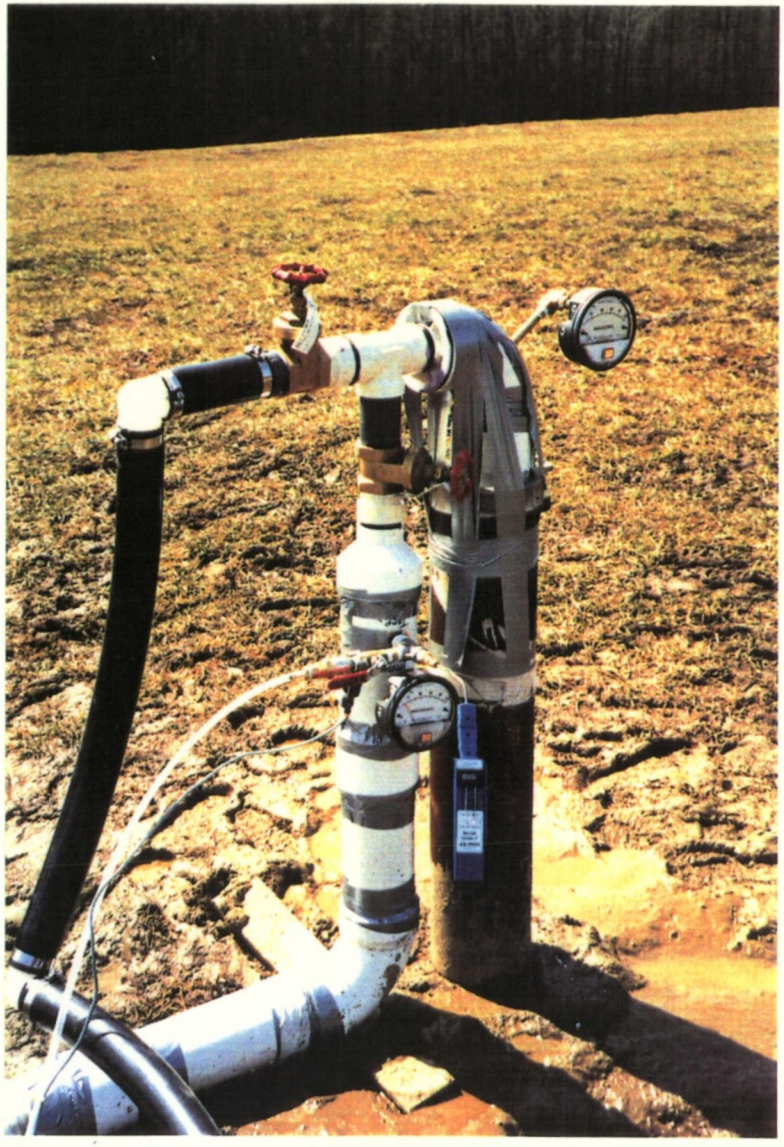


FIGURE 6-12 Close-Up of Extraction Well EX-1 Reconfigured for Slug Test. Black Piping is Inlet for Ambient Air Injection; White PVC Piping is used for the Extraction of Sample from Under the Cap (March 1992)

FIGURE 6-13 Long View of Black Piping Used to Introduce Ambient Air During Slug Testing. White Piping is Used to Extract Sample from Under Cap (March 1992)

FIGURE 6-14 Long View of Monitoring Probes, Passive Vents and Extraction Well on Cap (March 1992)

SECTION 7

7.0 REFERENCES

Clarke, A. N., M. M. Megehee and D. J. Wilson, "The Impact of Departures from Darcy's Law on Soil Vapor Stripping Design and Operation", Separation Science and Technology (in press 1992).

ECKENFELDER INC., January 1990. Feasibility Study, Shope's Landfill, Girard Township, Pennsylvania, Volumes I and II.

ECKENFELDER INC., July 1991. Work Plan for In Situ Vapor Stripping Pilot-Scale Treatability Study, Shope's Landfill, Girard Township, Pennsylvania.

ECKENFELDER INC., 1992. Revision to Health and Safety Plan for Lord-Shope Landfill Site. Original HASP, ECKENFELDER INC., September 1991, "Emergency/Disaster Contingency Plan for Remedial Design Activities Lord/Shope Landfill Site, Girard Township, Pennsylvania."

Lord Corporation, 1988. Quality Assurance Project Plan for the Recharacterization and Interim Monitoring of the Shope's Landfill Site, Girard Township, Pennsylvania.

USEPA, 1988. USEPA Compendium Method TO-14, "The Determination of Volatile Organic Compounds (VOCs) in Ambient Air using SUMMA Passivated Canister Sampling and Gas Chromatographic Analysis."

USEPA, 1989. USEPA Interim Final Document, "Guide for Conducting Treatability Studies under CERCLA," EPA/540/2-89/058, OERR, ORD, Cincinnati, Ohio, December 1989.